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Foreign Commodity Production Forecasting

October 1981

Determination of the Optimal Level for Combining Area and Yield Estimates

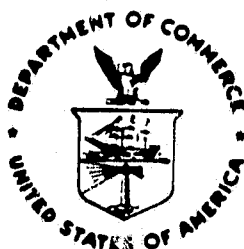
by M.M. Hixson and C.D. Jobusch

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Technical Report

DETERMINATION OF THE OPTIMAL LEVEL
FOR COMBINING AREA AND YIELD ESTIMATES

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16. Abstract <p>Since the eventual aim of crop inventory studies is production estimation, the stratification for area and yield estimates must be coordinated so that acceptable variances are obtained. The objective of this study was to determine the optimal level for combining area and yield estimates of corn and soybeans. Several levels of obtaining both area and yield estimates were considered: county, refined strata, refined/split strata, crop reporting district and state.</p> <p>Using the CCRA model form and smoothed weather data, regression coefficients at each level were derived to compute yield and its variance. Within stratum area variances were also computed.</p> <p>The variance of the yield estimates was largest at the state and smallest at the county level for both crops. The refined strata had somewhat larger variances than those associated with the refined/split strata and CRD.</p> <p>For production estimates, the difference in standard deviations among levels was not large for corn, but for soybeans the standard deviation at the state level was more than 50% greater than for the other levels. The refined strata had the smallest standard deviations. The county level was not considered in evaluation of production estimates due to lack of county area variances. Further studies should consider: (1) bias introduced using estimation at any of the levels, (2) the cost of computation of area and yield estimates at the varying levels, and (3) additional crops of interest.</p>					
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1. Introduction

The eventual aim of crop inventory studies is production estimation, not area or yield estimates alone. Production estimates can be made only at a level where area and yield strata intersect. The variance of the production estimates is dependent upon the means and variances of both area and yield in the stratum. Thus, it is important that the stratifications for area and yield estimation be coordinated, and that the levels for aggregation be selected so that acceptable variances are obtained.

In the AgRISTARS Foreign Commodity Production Forecasting (FCPF) Project, estimates are to be made for corn and soybeans area and yield in the United States as well as in Brazil and Argentina.

To make production estimates, NASA provides area estimates based on analysis of remotely sensed data and the USDA provides yield estimated from a regression model. In order to obtain the most precise production estimates, the levels of estimation must be coordinated. Thus, a study to determine the precision at several possible levels of aggregation was proposed.

2. Objectives

The overall objective of this study was to determine the optimal level for combining area and yield estimates of corn and soybeans. Production estimates and their variances were computed for several levels of area and yield estimates, and the resulting estimates were compared.

3. Approach

Iowa was selected to study the optimal level for combining area and yield estimates of corn and soybeans. This state was selected for study as it is included in the 1981 AgRISTARS pilot experiment. The year selected for evaluation ("current year") was 1978.

The level at which aggregation of area and yield to obtain production should occur is dependent upon the technology being utilized for estimation. If, for example, area or yield estimates made at a given level are biased or unreliable, then aggregation at that level would most likely be undesirable regardless of any potential gains in precision. A change in the technology utilized for estimation, however, might produce reliable estimates at the same level and be a viable candidate for aggregation. This investigation assessed the optimal

level with respect to the current technology. Current technology utilizes digital analysis of Landsat MSS data on sample segments to provide area estimates; regression models are developed from historical data and used with current weather data to provide yield estimates. Several levels of obtaining both area and yield estimates were considered: county, refined stratum, refined/split stratum, crop reporting district, and state.

The model form and variables included in the regression used by CCEA for yield estimation of corn and soybeans in Iowa were obtained. A weather data base with historical (at least 30 years) and "current year" weather data were needed for all the cooperative meteorological stations in Iowa. Historical and "current year" county area and yield estimates made by USDA/SRS in Iowa were acquired for the same time period.

Coefficients for the regression equations were derived to predict yield using the historical weather and yield data at each of the levels of aggregation. A weather smoothing function was utilized to provide estimates of meteorological variables for the various strata studied. Using the 1978 weather data, "current year" yield estimates were made for corn and soybeans in Iowa.

The yield estimate (\hat{Y}) and its variance were computed based on the regression equations. The yield estimate was then aggregated to the state level using area weights. The aggregated yield variance was used to determine which stratification systems were candidates for precise estimation methods.

For those levels of aggregation which appeared to be improvements over the currently used method, a further investigation into the effects of using the current area estimation methodology was conducted. Within stratum variances for the area of the crops of interest were obtained. The production estimate (\hat{P}) and its variance ($V(\hat{P})$) were computed for all the candidate aggregations. Evaluations compared the variances with one another.

3.1 Data Set Utilized

For development of regression models for yield, a historical series of yield estimates and meteorological data were required. The USDA/SRS county level statistics for yield of corn and soybeans were obtained from the Iowa state office for 1932-78. The 1932-77 data were used in computing the regression coefficients, and the 1978 data were acquired for results comparison.

Daily observations of temperature and precipitation for all the cooperative meteorological stations in the state of Iowa were purchased from the Iowa Geological Survey (1900-74) and some were supplied by another task (1975-78).

3.2 Levels of Aggregation

During the Large Area Crop Inventory Experiment (LACIE), aggregation of area and yield estimates to production was done at the state level. Thus, this would be one level for investigation.

For the state of Iowa, yield estimates will be made at the state level and one other level during the 1981 AgRISTARS pilot experiment. NASA/JSC requested that this level be the refined strata in the state (Figure 1). The yield modeling group, however, thinking that these strata were too broad, suggested a subdivision of them (Figure 1). This subdivision will be referred to as the refined/split strata in this report. Both of these levels are being considered for evaluation.

An additional level which seems to be natural to include is the crop reporting district level (Figure 2) as this has traditionally been a standard unit for the reporting of agricultural statistics. Also, the county level is included as the smallest possible unit using current yield estimation technology, as this is the smallest level for which historical yield estimates are available.

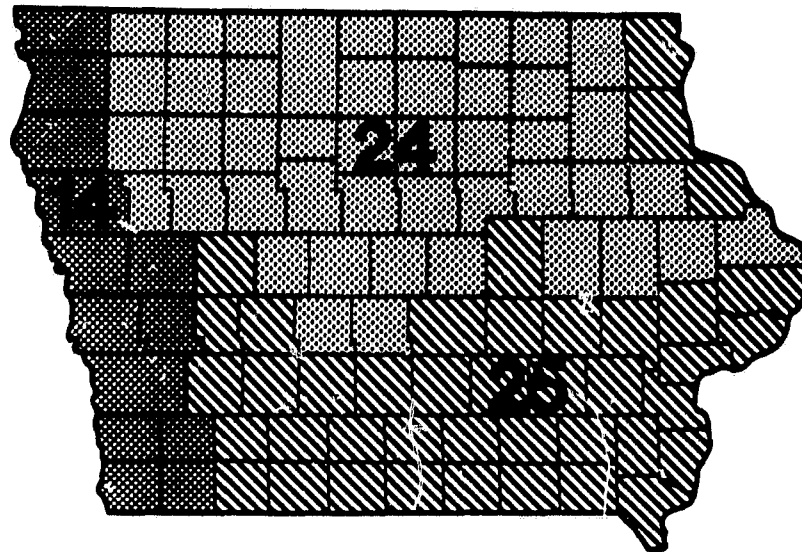
Some characteristics of the strata are presented in Tables 1-3. Means and variability between counties within the strata are described.

3.3 Meteorological Data Estimation

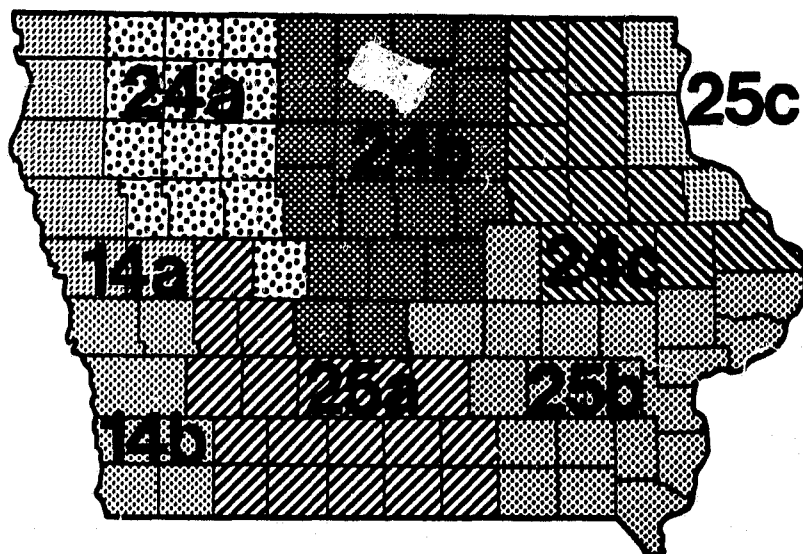
In order to study the various levels of aggregation, yield estimates were needed at each of the levels. To make yield estimates using current technology, meteorological data were needed for each stratum. Not all counties contain weather stations; besides, weighting by nearby weather stations may provide a better estimate of the overall weather of a county than the use of one weather station alone (Figure 3).

For this reason, a weather smoothing routine was utilized. Wagner (1971) devised an objective analysis technique which incorporates a low pass filter and provides a good analysis in sparse data areas or with data containing significant noise. Furthermore, the characteristics of the applied filter function are easily calculated and the analysis technique is quite forgiving in terms of the sensitivity of choosing a filter function for a given data set. This technique was initially devised to remove high frequency fluctuations in the initial condition fields used for numerical weather forecasting. However, the consistency and speed of the technique make it a viable technique for our purposes.

Odell (1975) compared ten techniques for interpolation for irregularly spaced sparse data: composite average, nearest neighbor, least squares linear regression, least squares convex hull, average



REFINED STRATA



REFINED/SPLIT STRATA

Figure 1. Maps of the refined strata developed at NASA/JSC (top) and the refined/split strata as subdivided for the yield modeling effort (bottom).

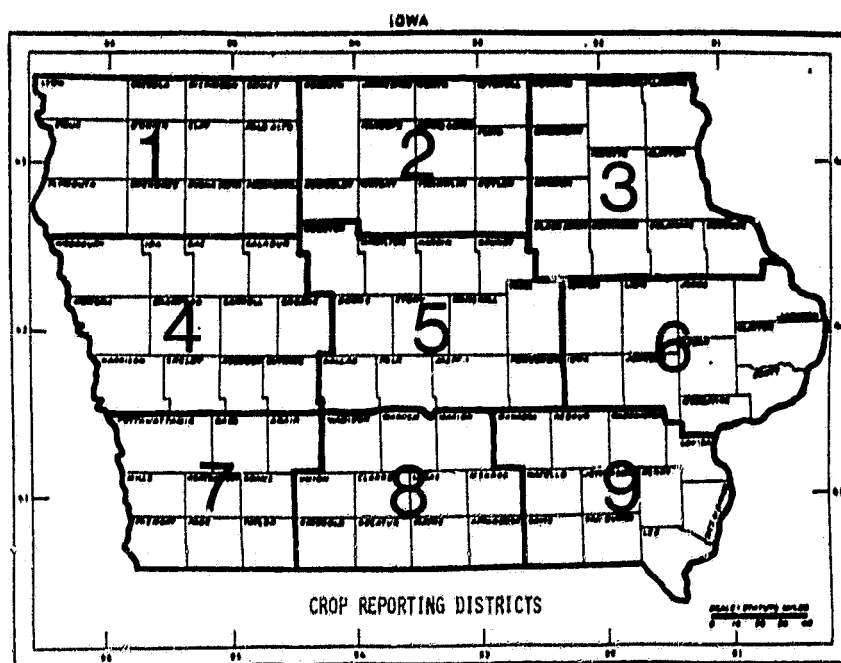


Figure 2. Map of the crop reporting districts in Iowa.

Table 1. Some characteristics of the refined strata. Means and variability are described for corn and soybeans proportions and yields.

DESCRIPTION OF PROPORTIONS FOR REFINED STRATA

Stratum	CORN			SOYBEANS			No. of Counties
	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	
14	37.0	4.3	11.6	16.7	3.8	22.6	13
24	37.7	9.0	35.4	25.5	9.0	35.4	45
25	25.7	8.7	33.7	13.3	5.0	37.3	41

DESCRIPTION OF YIELDS FOR REFINED STRATA

Stratum	CORN			SOYBEANS			No. of Counties
	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	
14	85.1	23.4	27.5	32.3	3.9	12.1	13
24	99.6	15.7	15.8	32.6	4.0	12.3	45
25	94.7	18.2	19.2	31.0	4.6	14.8	41

Table 2. Some characteristics of the refined/split strata. Means and variability are described for corn and soybeans proportions and yields.

DESCRIPTION OF PROPORTIONS FOR REFINED/SPLIT STRATA

Stratum	CORN			SOYBEANS			No. of Counties
	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	
14A	39.3	2.9	7.5	14.1	2.6	18.7	6
14B	35.0	4.4	12.6	19.0	3.1	16.4	7
24A	39.7	2.0	5.1	29.7	6.6	22.1	13
24B	39.7	3.2	8.1	29.3	5.4	18.4	20
24C	32.3	5.2	16.1	14.6	7.1	48.9	12
25A	21.3	8.8	41.1	12.4	3.5	28.4	18
25B	22.2	5.7	25.8	0.9	0.2	20.2	3
25C	30.2	6.7	22.2	16.0	2.9	18.0	20

DESCRIPTION OF YIELDS FOR REFINED/SPLIT STRATA

Stratum	CORN			SOYBEANS			No. of Counties
	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	
14A	81.7	22.9	28.0	32.2	4.8	14.9	6
14B	88.0	23.7	26.9	32.4	3.1	9.6	7
24A	97.5	18.5	19.0	33.5	4.1	12.2	13
24B	103.6	14.1	13.6	33.0	3.8	11.5	20
24C	95.4	13.2	13.8	30.8	3.9	12.7	12
25A	85.6	20.4	23.8	29.1	4.3	14.8	18
25B	102.4	12.5	12.2	32.9	4.2	12.8	20
25C	98.6	8.4	8.5	30.0	2.8	9.3	3

Table 3. Some characteristics of the crop reporting districts. Means and variability are described for corn and soybeans proportions and yields.

DESCRIPTION OF PROPORTIONS FOR CROP REPORTING DISTRICTS

Stratum	CORN			SOYBEANS			No. of Counties
	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	
North West	39.5	2.3	5.7	26.8	8.5	31.7	12
North Central	39.9	2.1	5.2	30.7	5.4	17.5	11
North East	30.2	7.1	23.5	11.7	8.9	75.7	11
West Central	38.3	4.7	12.4	19.3	8.3	43.1	12
Central	37.6	4.9	13.1	25.1	6.5	25.9	12
East Central	33.1	5.3	16.0	13.5	5.4	40.1	10
South West	29.7	5.6	19.6	17.5	4.0	22.8	9
South Central	16.3	4.8	29.3	10.6	2.3	22.0	11
South East	27.0	6.9	25.7	16.5	3.1	18.7	11

DESCRIPTION OF YIELDS FOR CROP REPORTING DISTRICTS

Stratum	CORN			SOYBEANS			No. of Counties
	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	
North West	93.1	21.0	22.6	33.8	4.3	12.7	12
North Central	99.8	14.1	14.1	32.2	3.5	10.9	11
North East	95.9	12.7	13.2	29.8	3.5	11.7	11
West Central	89.9	21.0	23.4	31.8	3.9	12.3	12
Central	106.8	12.8	12.0	33.9	3.8	11.2	12
East Central	100.5	12.7	12.6	33.8	3.6	10.7	10
South West	85.7	25.1	29.3	31.2	3.4	10.9	9
South Central	86.0	18.7	21.7	28.2	4.7	16.7	11
South East	101.9	12.8	12.6	31.7	4.4	13.9	11

		X
X	X	
X	County k	X
	X	

Figure 3. An example of a situation when weighting by weather stations in adjacent counties may be beneficial in providing good estimates of weather for county k. Each x represents a meteorological station.

linkage, average linkage with directional correlation, Wagner's objective analysis, modified linkage, and modified least squares. These techniques were tested in terms of their ability to interpolate five years of wheat yield data across the state of North Dakota (45 data points) based on seven stations of wheat yield data. The weighted linear regression technique appeared to be the best technique with the objective analysis, least squares linear regression, and the modified average linkage coming in close behind. However, the weighted linear regression is computationally time consuming, the least squares linear regression is not well behaved on the boundaries, and the modified linkage does not reflect directional trends in the data. The objective analysis approach provides a smooth well-behaved surface and is computationally fast. Its major deficiency is that the original data points are not fit exactly. However, if noise exists in the input data, this can be advantageous. And, use of the cooperative meteorological station data makes this a reasonable assumption.

Integration of data fields (raster form) produced by the objective analysis routine is sometimes required in order to obtain averages of meteorological (or other) data over some polygonal area. In order to accomplish this, the subroutines of Rios (1979) were utilized. A driver program was written to enable averages, mean square errors, and variances to be calculated for polygonal areas with 39 or fewer vertices. The polygon may contain both convex and concave features. This capability enables averages for a farmer's field, or an entire political subdivision or stratum to be calculated.

The general procedure utilized by the objective analysis technique is illustrated by Figure 4. A grid of a user-selected density is placed over the area of interest. Then the available met station data are used to specify the values at the nearest grid intersection points. The objective analysis procedure then uses gradient and Laplacian weights to specify the values at all grid intersections (Wagner, 1971). Finally, an estimate of the smoothed variable can be made over any polygon of interest by averaging over the grid points within that polygon.

The objective analysis technique was found to perform well in interpolating maximum temperature, minimum temperature, and precipitation on both a monthly and a daily basis for a case study in May 1977 in Oklahoma (Pitts, 1980).

Based upon the favorable results obtained by other investigators, the FORTRAN coded programs for objective analysis were obtained from Dr. David E. Pitts of NASA/JSC. The programs were modified to fit our specific needs; the resulting listings are presented in Appendix A.

A meteorological data smoothing experiment was conducted to determine how the objective function should be utilized. One month of daily data (June 1974) for all met stations in Iowa was used in the study. There were several factors in the experiment: grid size (25 x

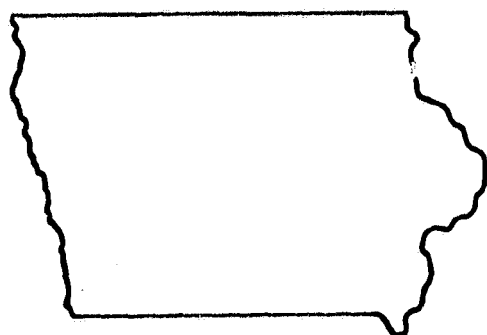
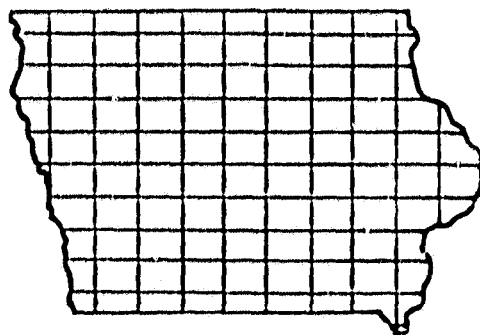
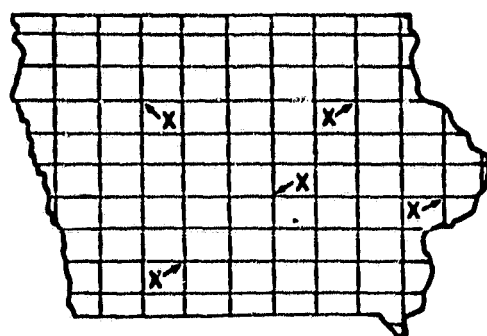
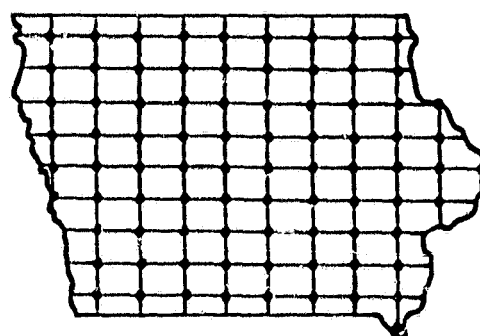
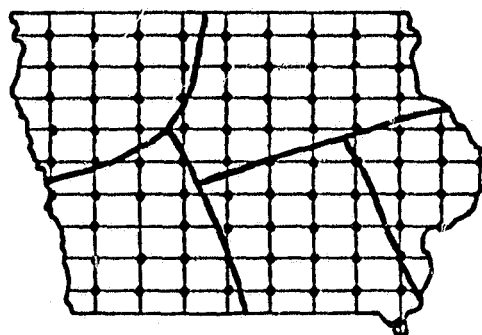
**Area of Interest****Grid Defined****Stations "Moved" to
Nearest Grid Intersection****Objective Analysis
Specifies All Grid Points****Average All Grid Points
Within Polygons of Interest**

Figure 4. Schematic diagram of the steps in the meteorological data smoothing routine used to obtain meteorological estimates for polygons of interest in Iowa.

25, 32 x 32, 64 x 64), level of smoothing (daily vs. monthly), gradient weight (1,10), and Laplacian weight (1,10). The results were evaluated by examining the mean square error of fit to station data and the maximum change in specified values.

The first observation from this experiment was that using gradient and Laplacian weights of 10 caused too much change in the specified values. A difference of up to about one inch of precipitation was observed. Thus, the remainder of the experiment was analyzed using weights of one only.

The maximum absolute deviation from specified values was examined for the three grid sizes (Table 4). The 64 x 64 grid provided estimates much closer to the specified values than the other two grid sizes. The root mean square error was examined for daily vs. monthly averaging (Table 5). It was found that averaging met data to monthly values and then smoothing the monthly averages performed significantly better than smoothing daily values and then averaging the smoothed values to obtain a monthly estimate.

The parameters selected for use in our study were: grid size 64 x 64 over Iowa, gradient and Laplacian weights of 1.0, and smoothing of monthly average values.

3.4 Yield and Yield Variance Estimation

Estimates of yield at all the levels of aggregation were required for this study. To do this, the variables used in the CCEA state level model were utilized (Table 6). Regression coefficients were developed for each set of strata utilizing 1931-77 meteorological data and 1932-77 USDA/ESCS estimates of county level yields. Data from 1970 were not used in the derivation of regression coefficients for corn due to the corn blight which occurred during that year. The meteorological data inputs were daily reports of minimum temperature, maximum temperature, and precipitation for the strata as computed by the Wagner variational analysis technique.

The programs used to compute the yield and the yield variances were written in SAS. A sample program for each crop is given in Appendix B.

The variance of the yield estimates was computed from the regressions by:

$$V(\hat{Y}) = \sigma_{y|x}^2 (1 + x' (X'X)^{-1} x).$$

Using this formula, a variance was computed for each of the strata in each of the candidate stratification systems.

Table 4. Some results from the meteorological data smoothing experiment. The table shows daily maximum absolute deviations of smoothed values from the specified station values.

Weather Variable	Grid Size		
	25 x 25	32 x 32	64 x 64
Maximum Temperature	2.93	2.45	0.77
Minimum Temperature	2.08	1.39	0.63
Precipitation	0.06	0.04	0.01

Table 5. Some results from the meteorological data smoothing experiment. The table shows the root mean square error of smoothed values from the specified station values.

Weather Variable	Grid Size	RMS Error	
		Daily Smooth	Monthly Smooth
Temperature	32 x 32	4.88	0.52
	64 x 64	NA*	0.17
Precipitation	32 x 32	6.67	0.92
	64 x 64	NA	0.17

* NA - Not Available

Table 6. Model variables for the regressions predicting yield of corn and soybeans in Iowa.

Corn	Soybeans
Linear trend 1941-50	Linear trend 1932-74
Linear trend 1961-72	Cumulative precipitation October - April DFN
May temperature x precipitation interaction	May temperature x precipitation interaction
June temperature x precipitation interaction	June temperature DFN *
June temperature (DFN) ²	July precipitation DFN
July precipitation DFN	July temperature DFT
July temperature DFT	August precipitation DFN
July temperature (DFT) ²	August precipitation (DFN) ²
August temperature DFT	August temperature DFT

* DFN = Departure From Normal
DFT = Departure From Trend

To compare the precision of the several levels, a yield estimate aggregated to the state level was computed. The variance of the aggregated estimates must account for both the variance and covariances of the estimates. Thus, if

$$\hat{Y}_L = \sum_i W_i \hat{Y}_i,$$

then its variance can be computed by:

$$V(\hat{Y}_L) = \sum_i W_i^2 V(\hat{Y}_i) + 2 \sum_{i < j} \text{Cov}(\hat{Y}_i, \hat{Y}_j) W_i W_j$$

where \hat{Y}_L is the aggregated state yield estimate, W_i is the area weight for stratum i , and \hat{Y}_i is the regression yield estimate for stratum i .

3.5 Area and Area Variance Estimation

The area estimates used in the study were the 1978 final area harvested estimates made by the USDA/SRS for the Iowa counties. The variance of these estimates is not computed due to the complex estimation methodology employed. More importantly, the variance of the USDA estimates would most likely differ from that obtained utilizing the AgRISTARS "current technology" of estimating crop areas based on analysis of Landsat data over sample segments.

The variance of the area estimates was computed using the methods described by Chhikara and Perry (1980). The number and distribution of agricultural segments in a region were obtained from NASA. For regions without Landsat imagery, the unobserved potential segments were assigned the same distribution of percent agricultural as the observed segments in that county.

Two methods (Chhikara and Perry, 1980) were available to fit the model:

$$\hat{\sigma}_x^2 = Ax^B,$$

one method based on field sizes and the other a pixel-based method. Both methods were used for comparison and verification.

In the field size model:

$$\sigma_{x_0}^2 = \frac{4}{9} \bar{P} (1 - \bar{P})$$

was computed. The field size estimates were obtained from Pitts (1980) data base. Counties were assigned an average field size equal to that of any sample segments within the county. Counties without segments were assigned the field size of a county with similar farm size in geographic proximity.

The second computational method, based on pixels, used the equation:

$$\sigma_{x_0}^2 = \alpha_1(1 - \hat{P}) + \alpha_2 \hat{P}^2 + \alpha_3 (0.3682 - \hat{P} + \hat{P}^2).$$

The programs which were utilized to estimate area variances are presented in Appendix C.

3.6 Aggregation Methodology

For each of the strata in each stratification system, the production was computed as:

$$\hat{P}_1 = \hat{A}_1 \times \hat{Y}_1$$

where \hat{P}_1 , \hat{A}_1 , and \hat{Y}_1 are the estimates of production, area, and yield, respectively, in stratum 1.

The state-level aggregated production estimate was computed using the methods of stratified estimation presented in Cochran (1963).

For each stratum, the variance of production was computed as:

$$V(\hat{P}_1) = V(\hat{A}_1 \times \hat{Y}_1) = V(\hat{A}_1)\mu_{\hat{Y}_1}^2 + V(\hat{Y}_1)\mu_{\hat{A}_1}^2 + V(\hat{A}_1)V(\hat{Y}_1)$$

For the aggregated state estimate,

$$V(\hat{P}_L) = V(\sum_1 \hat{P}_1) = \sum_1 V(\hat{P}_1) + 2 \sum_{1 < j} \text{Cov}(\hat{P}_1, \hat{P}_j).$$

4. Results and Discussion

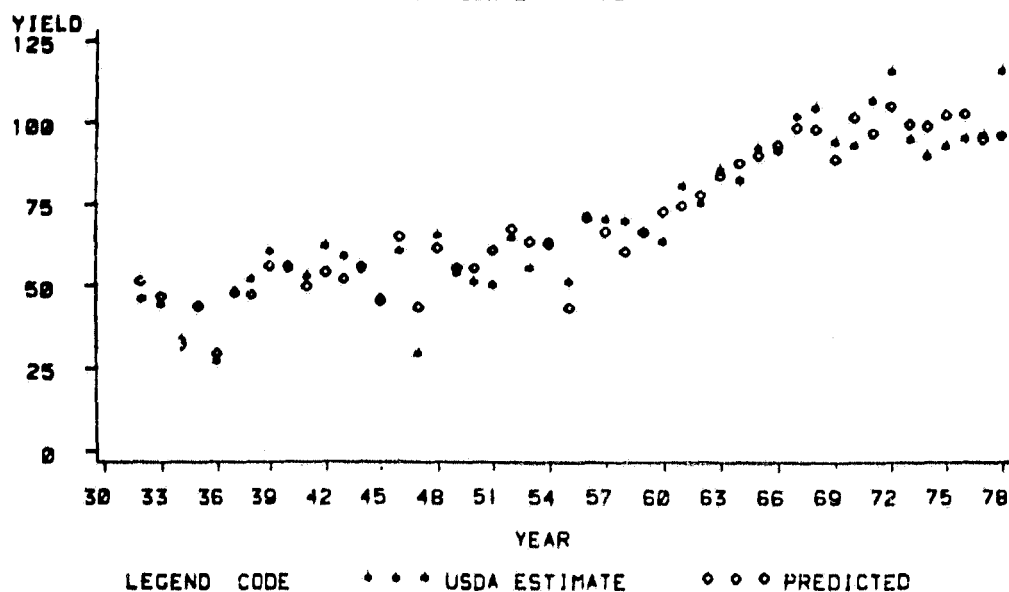
4.1 Regression Analysis

A selection of results from the regression analyses are illustrated in Figures 5-9. At the county level, the correlations between values predicted by the regression and USDA observed values had a substantial range. Linn County, with r-square values of 0.93 and 0.92 for corn and soybeans, respectively, is fairly representative of a high correlation situation. Lyon County (r-squares of 0.78 and 0.76) is representative of a lower correlation.

In estimating the yield of corn and soybeans at the crop reporting district level, the correlations between estimated and observed values did not have such a large range as for counties. This is due (at least in part) to the smoothing effects achieved by the consideration of a larger geographic region. The results for the state are illustrated also.

IOWA CORN MODEL

LINN COUNTY
R-SQUARE = .930



IOWA SOYBEAN MODEL

LINN COUNTY
R-SQUARE = .918

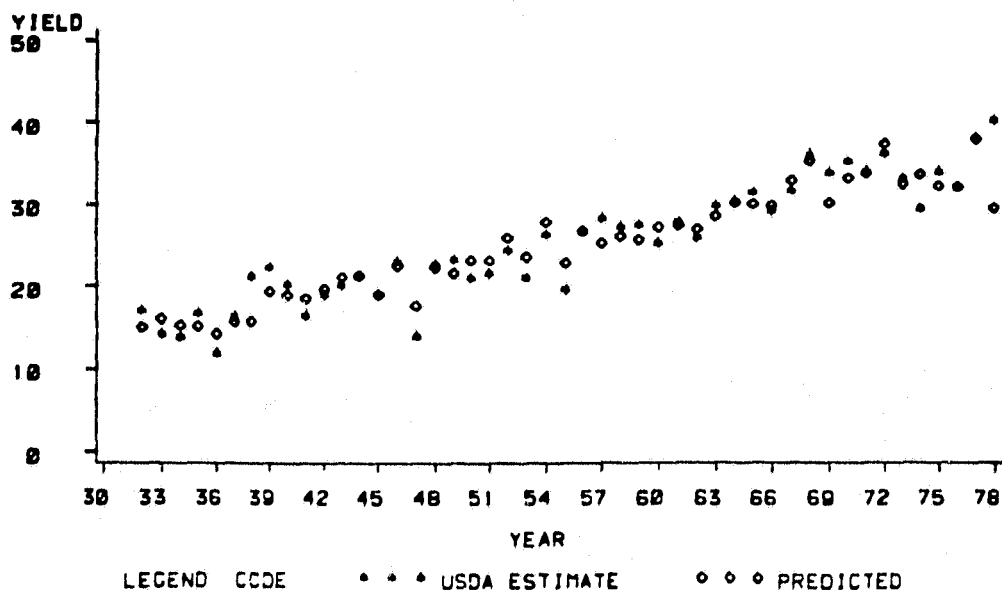
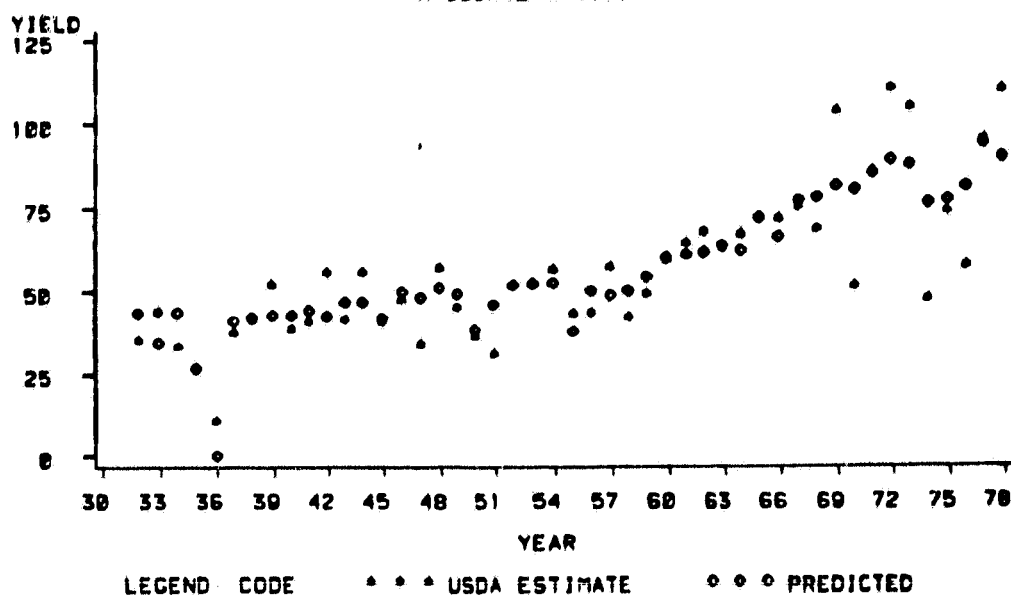


Figure 5. Comparison of corn and soybean yields predicted by the regression equations with USDA/SRS estimates for Linn County, Iowa.

IOWA CORN MODEL

LYON COUNTY

R-SQUARE = .777



IOWA SOYBEAN MODEL

LYON COUNTY

R-SQUARE = .761

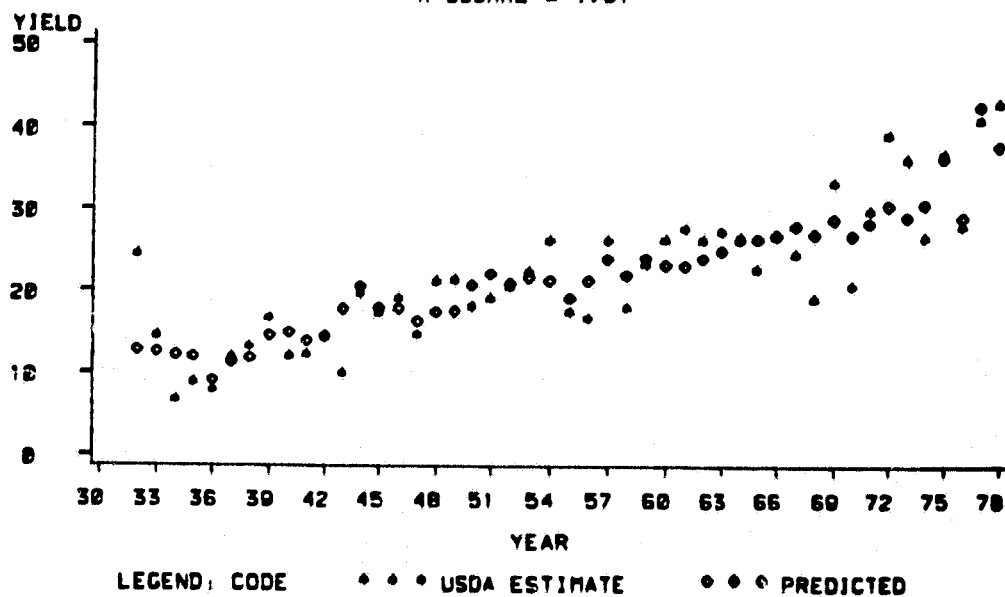
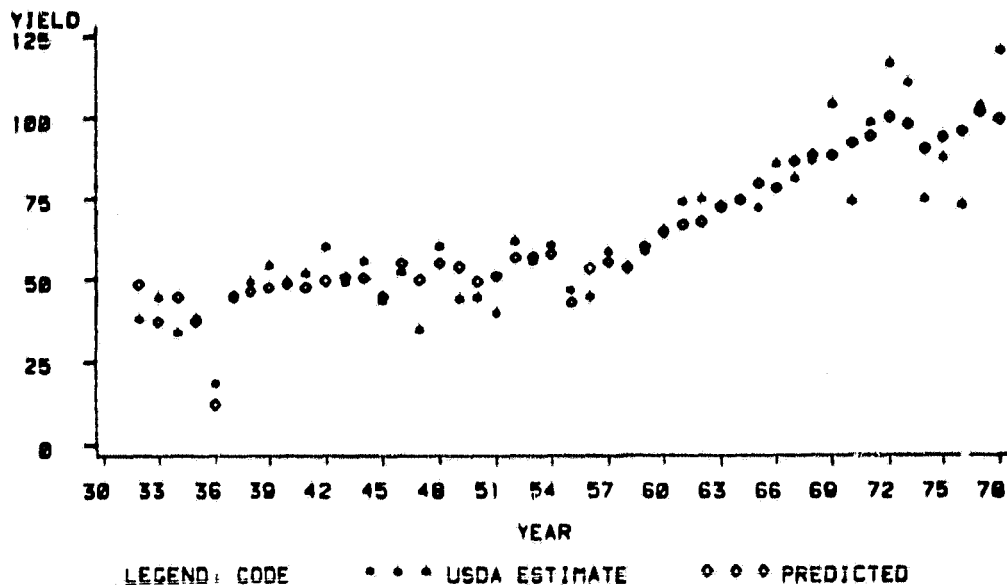


Figure 6. Comparison of corn and soybean yields predicted by the regression equations with USDA/SRS estimates for Lyon County, Iowa.

IOWA CORN MODEL

NORTH WEST CROP REPORTING DISTRICT

R-SQUARE = 866



IOWA SOYBEAN MODEL

NORTH WEST CROP REPORTING DISTRICT

R-SQUARE = 845

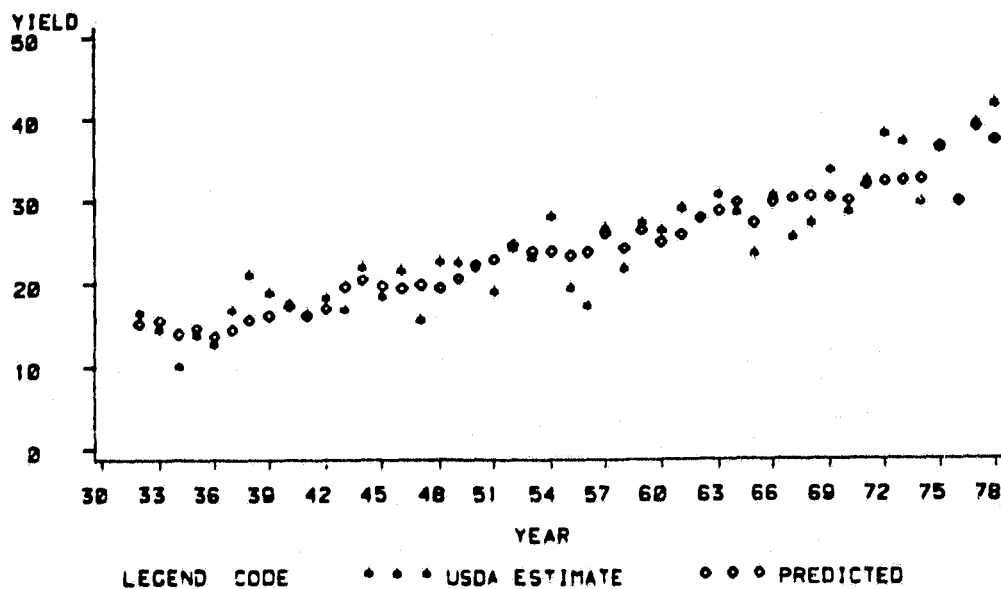
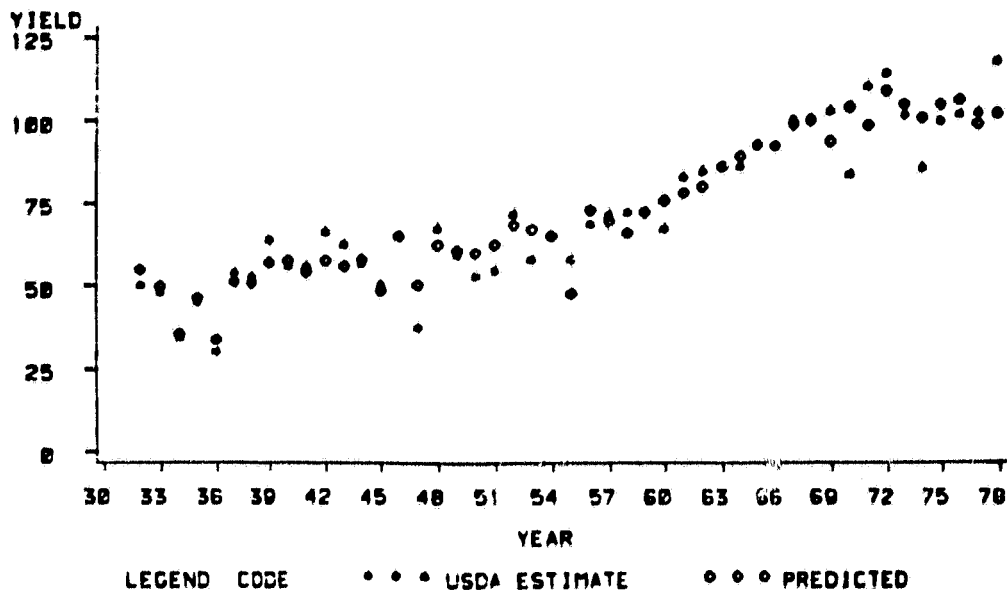


Figure 7. Comparison of corn and soybean yields predicted by the regression equations with USDA/SRS estimates for the North West Crop Reporting District in Iowa.

IOWA CORN MODEL **EAST CENTRAL CROP REPORTING DISTRICT** **R-SQUARE = .930**



IOWA SOYBEAN MODEL **EAST CENTRAL CROP REPORTING DISTRICT** **R-SQUARE = .912**

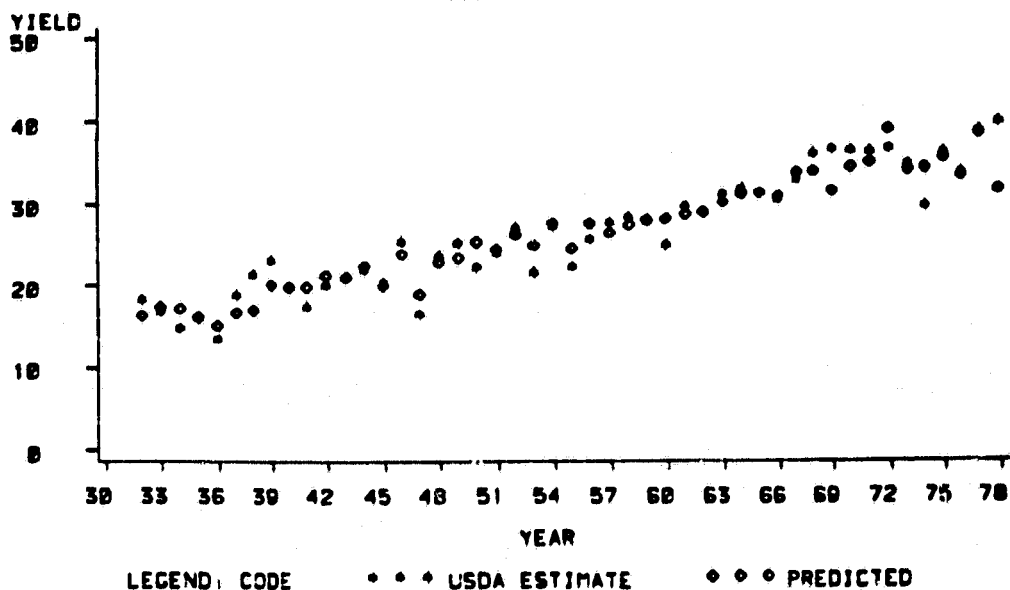
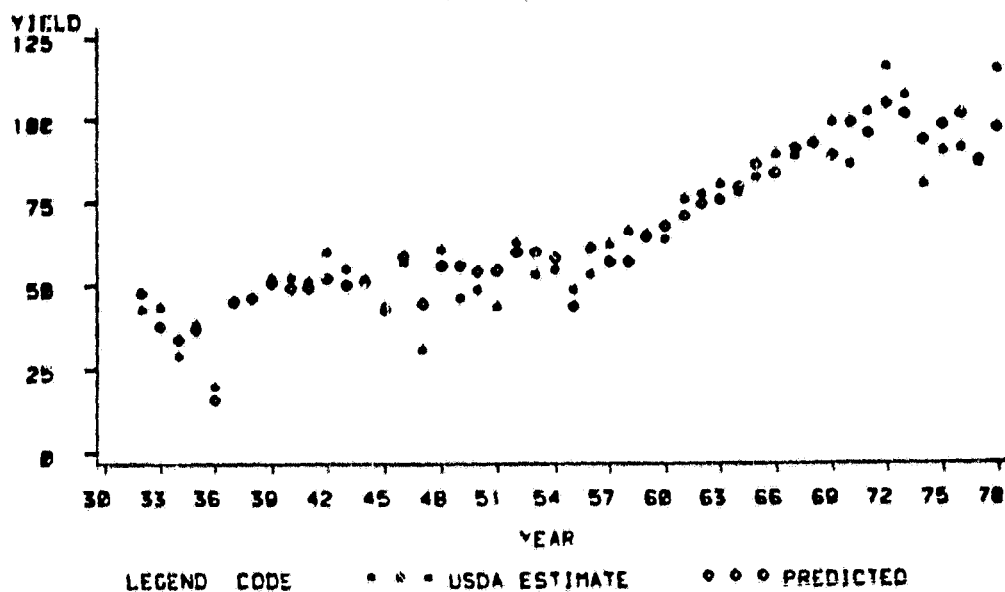


Figure 8. Comparison of corn and soybean yields predicted by the regression equations with USDA/SRS estimates for the East Central Crop Reporting District in Iowa.

IOWA CORN MODEL

ENTIRE STATE

R-SQUARE = .921



IOWA SOYBEAN MODEL

ENTIRE STATE

R-SQUARE = .871

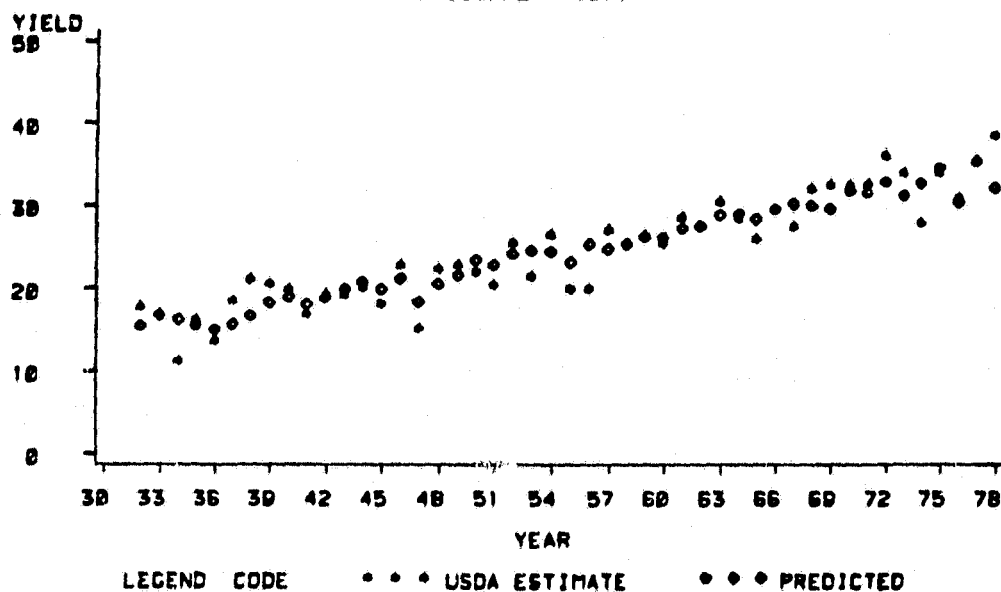


Figure 9. Comparison of corn and soybean yields predicted by the regression equations with the USDA/SRS estimates for the state of Iowa.

4.2 Variance of Yield Estimates

The variance of the yield estimates was computed for each stratum in each of the stratification systems from the regression equations. The aggregate of these results to the state level is shown in Table 7 and illustrated in Figure 10.

For both crops, the state level had the largest variance, and the county level had the smallest variance. The refined strata had somewhat larger variances than those associated with the refined/split strata. The variances for the CRD and the refined/split strata are about the same.

4.3 Variance of Production Estimates

The variance of the production estimates, computed based on the preceding results, is shown in Table 8 and is illustrated in Figures 11 and 12. There were only small differences between the values computed using the field size and pixel size methods for computing area variances. Thus, the same discussion applies no matter which method is selected.

For corn, the difference in the standard deviations among levels is not great. The differences for soybeans are quite apparent, however, with the standard deviation at the state level being more than 50% greater than for the other levels. For both crops, the refined strata had the smallest standard deviations.

This result is somewhat surprising since the aggregated yields had shown this method to be of slightly lower precision. What is probably being illustrated, however, is the precision gained by having fewer strata. There are only three refined strata compared with eight refined/split strata and nine crop reporting districts. Due to the strata correlations, relatively more precision was obtained with the fewer refined strata.

5. Summary and Conclusions

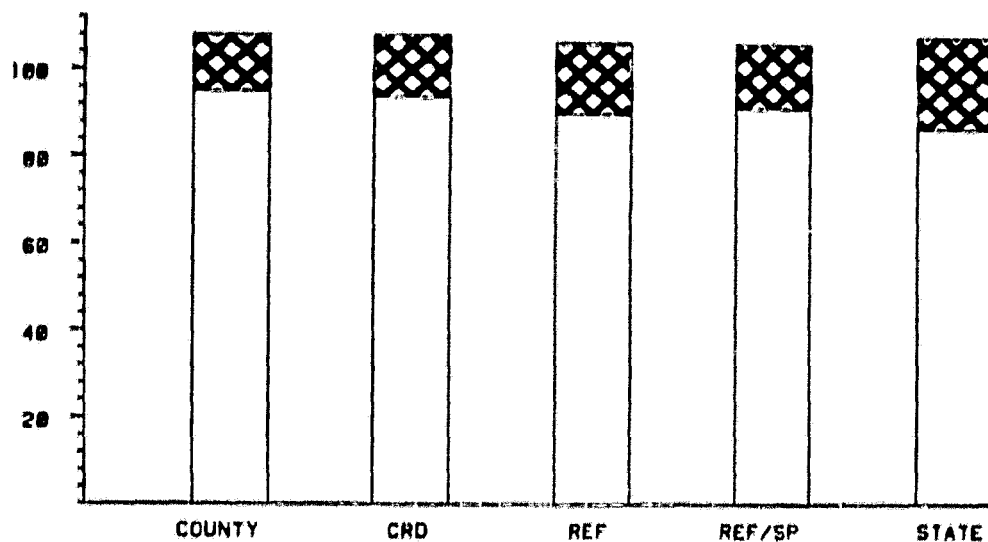
Aggregation of area and yield to production at the state level was the least precise of the methods examined. The crop reporting district, refined strata, and refined/split strata had similar levels of precision of production estimates.

In examining the variance of yield estimates, the aggregated results from estimation at a county level showed a high precision.

Table 7. The variance of yield estimates obtained using each level of estimation.
The individual stratum results were aggregated to the state level for comparison.

Stratification System	No. of Strata	CORN		SOYBEANS	
		Variance	Standard Deviation	Variance	Standard Deviation
STATE	1	109.6	10.5	14.2	3.8
CRD	9	49.0	7.0	6.2	2.5
COUNTY	99	39.9	6.3	4.3	2.1
REFINED	3	66.4	8.1	9.0	3.0
REF/SPLIT	8	51.4	7.2	6.5	2.5

ESTIMATED 1978 CORN YIELD FOR IOWA



ESTIMATED 1978 SOYBEAN YIELD FOR IOWA

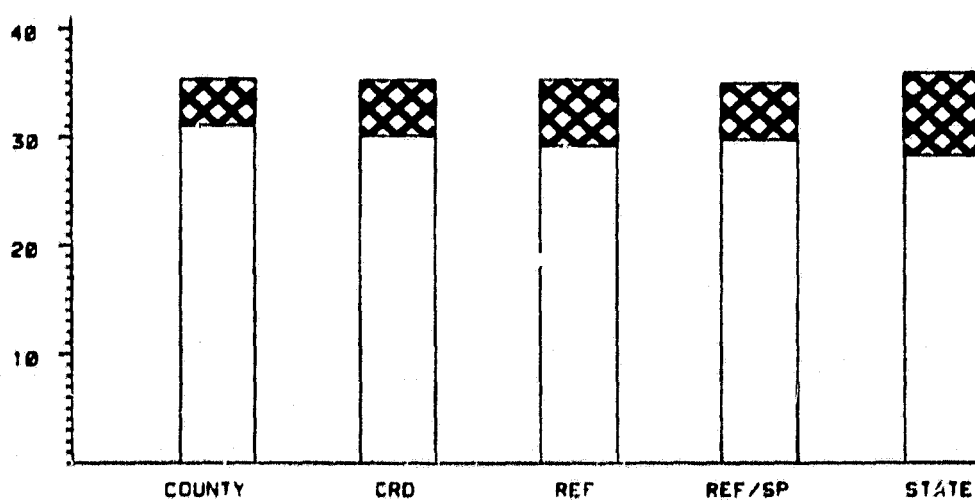


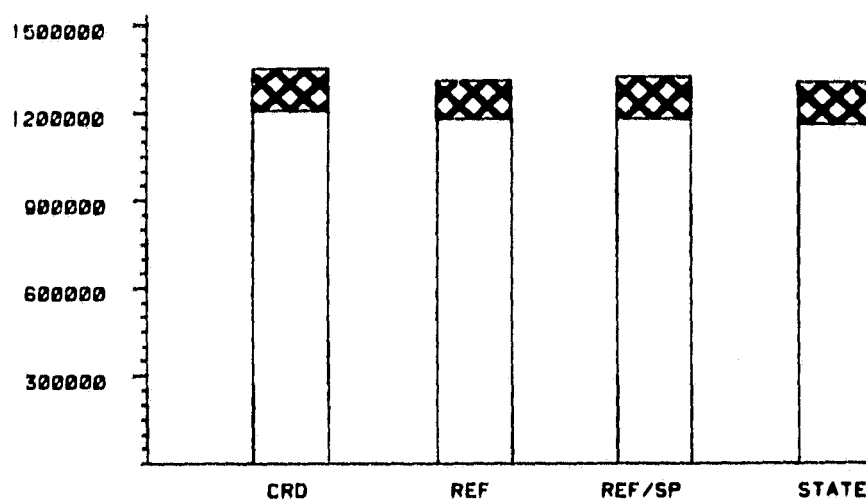
Figure 10. The estimated yield of corn and soybeans at the state level for each of the stratification systems. The shaded area is the estimated yield plus and minus one standard deviation.

Table 8. Standard deviation of state-level production estimates made at several levels of aggregation. Units are in thousands of bushels.

Level of Aggregation	Field Size Method		Pixel Size Method	
	Corn	Soybeans	Corn	Soybeans
CRD	72.2	14.8	72.2	14.8
Refined	63.8	13.8	63.3	13.6
Refined/Split	71.1	14.2	71.0	14.1
State	71.5	22.5	69.2	22.2

ESTIMATED 1978 CORN PRODUCTION FOR IOWA

FIELD SIZE VARIANCE ESTIMATION METHOD



ESTIMATED 1978 SOYBEAN PRODUCTION FOR IOWA

FIELD SIZE VARIANCE ESTIMATION METHOD

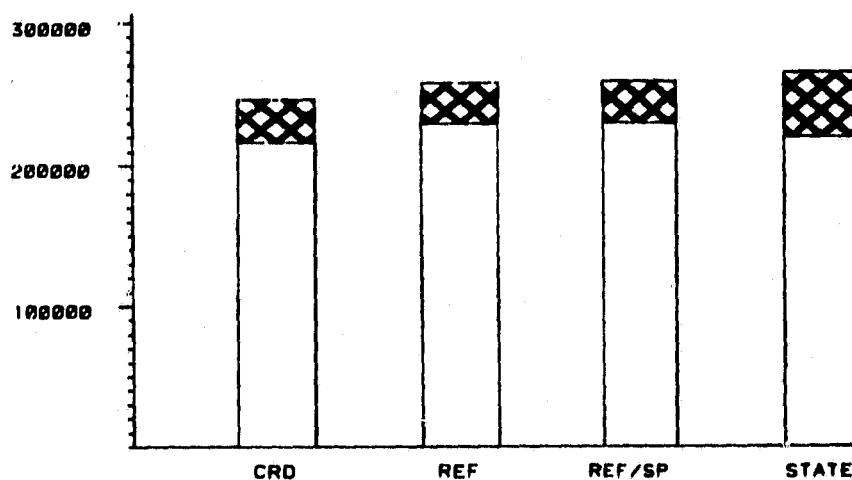
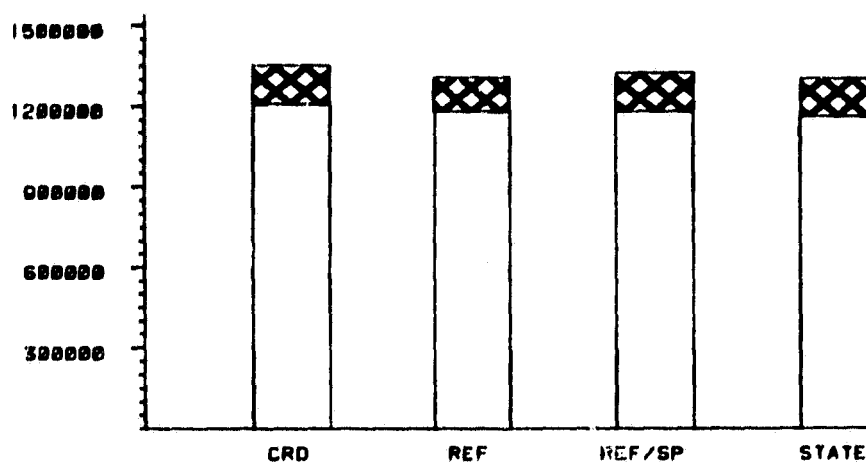


Figure 11. Estimated corn and soybean production for Iowa using the field size variance estimation method. Shaded area is estimated production plus and minus one standard deviation.

ESTIMATED 1978 CORN PRODUCTION FOR IOWA

PIXEL SIZE VARIANCE ESTIMATION METHOD



ESTIMATED 1978 SOYBEAN PRODUCTION FOR IOWA

PIXEL SIZE VARIANCE ESTIMATION METHOD

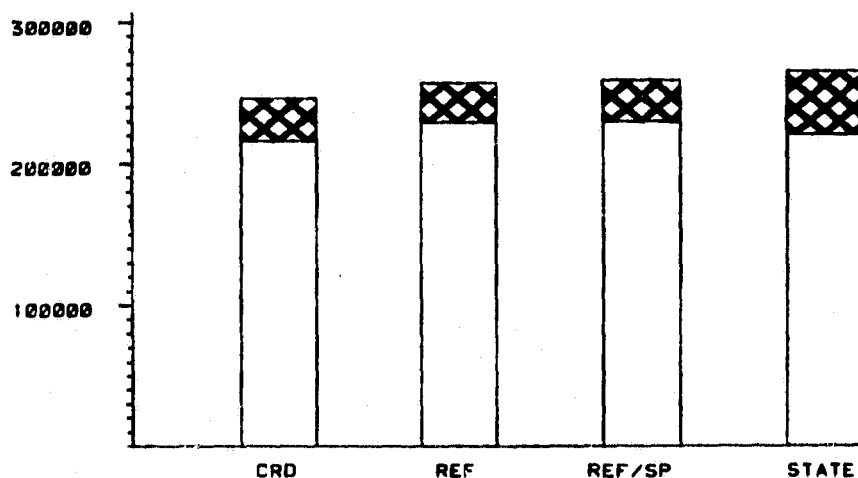


Figure 12. Estimated corn and soybean production for Iowa using the pixel size variance estimation method. Shaded area is estimated production plus and minus one standard deviation.

Unfortunately, we did not have a mechanism for estimation of area variances at the county level. This level for estimation should be considered, however, because of its high precision for yield.

The results of this study provide a first step in determination of the optimum level for combining area and yield estimates to obtain production. Two aspects not considered in this study should be part of a further analysis: (1) bias introduced using area or yield estimation at any of the levels, (2) the cost of computation of area and yield estimates at the varying levels, and (3) differences in the optimal level due to the crop of interest.

The bias of estimates was considered in this study only to the extent that it did not appear that any of the estimates were biased with respect to the estimates made using any other level of estimation. It may be, however, that either area estimates, yield estimates, or both may have a bias when estimated at one of the levels. The area estimates are currently made at a refined stratum level; no information is available on the potential bias introduced by estimating areas on any smaller geographic region. The yield estimates are now made generally at the state level. Biases may be introduced due to the density of weather stations available for estimating the parameters of the regression equation. A technique such as was utilized in this study may be one possible solution to this problem. However, it is possible that the resulting yields should be smoothed rather than the input meteorological data since the relationship between the input data and predicted values is not linear in the input variables.

The costs of computing the area and yield components must also be considered before a final recommendation can be made. The basis for the decision will consist of consideration of the variances and standard deviations computed as a part of this investigation coupled with cost information for computation of area and yield estimates at each of the potential levels of aggregation. The analysis can be carried out based on sample survey design theory such as described by Cochran (1963).

The results for corn and soybeans were substantially different, with the level at which corn is aggregated making less difference than the level at which soybeans are aggregated. Thus, additional crops of interest such as small grains should be examined.

In summary, the results of this study indicate that aggregations should be performed at a level below the entire state. Selection of the most appropriate level, however, requires further study of bias, cost, and crop-dependent differences.

6. References

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6. Rios, A. 1979. "As Built" Design Specification for BTMAIN Processor Program. NASA, Johnson Space Center, Houston, Texas. JSC-14834, Job Order 71-475, LEC 13322.
7. Wagner, K.K. 1971. Variational Analysis Using Observation and Low-Pass Filtering Constraints. Master's Thesis, Dept. of Meteorology, University of Oklahoma, Norman, Oklahoma.

Appendix A. FORTRAN programs used to carry out the meteorological smoothing routine.

```

C SM000010
C=====SM000020
C SM000030
C SMOOTH FORTRAN SM000040
C WRITTEN BY DAVE PITTS (J.S.C.) SM000050
C MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80 SM000060
C SM000070
C SMOOTH FORTRAN IS THE INITIAL CALLING PROGRAM FOR A WEATHER DATA SM000080
C SMOOTHING FUNCTION SM000090
C SM000100
C=====SM000110
C SM000120
C VARIABLES SM000130
C SM000140
C MAXLAT MAXIMUM LATITUDE ON MAP SM000150
C MINLAT MINIMUM LATITUDE ON MAP SM000160
C MAXLNG MAXIMUM LONGITUDE ON MAP SM000170
C MINLNG MINIMUM LONGITUDE ON MAP SM000180
C ISIZE NUMBER OF GRID IN NORTH-SOUTH DIRECTION SM000190
C JSIZE NUMBER OF GRID IN EAST-WEST DIRECTION SM000200
C L NUMBER OF PAIRS OF VERTICES OF POLYGON SM000210
C IDEBUG EQUALS L IF EXTRA PRINTOUT IS NEEDED FOR DEBUGGING SM000220
C IBUF(2) NUMBER OF PSEUDOZONE OR FIELD DESCRIBED BY POLYGON SM000230
C IPOLY NUMBER OF PLOYGONS TO BE PLACED OVER THE FUNCTION U SM000240
C SM000250
C ISIZE, MAXLAT, AND MINLAT MUST BE ADJUSTED SO THAT ISCALE IS AN SM000260
C INTEGER. SM000270
C JSIZE, MAXLNG, AND MINLNG MUST BE ADJUSTED SO THAT JSCALE IS AN SM000280
C INTEGER. SM000290
C SM000300
C=====SM000310
C SM000320
C IMPLICIT INTEGER*4 (I-N), REAL*8 (A-H, O-Z) SM000330
C REAL*8 XLAT(500), XLONG(500), TMAX(500), TMIN(500), PREC(500) SM000340
C REAL*8 P(64,64), U(64,64), DIFF(64,64) SM000350
C REAL*8 MAXLAT, MINLAT, MAXLNG, MINLNG SM000360
C INTEGER*4 IBUF(80), IX6(512) SM000370
C INTEGER*4 NTIMES SM000380
C SM000390
C=====SM000400
C SM000410
C 5 READ (5,101,END=9200) MAXLAT,MINLAT,MAXLNG,MINLNG,ISIZE,JSIZE,K, SM000420
C +AA,ALF2,ALF4,ERR,MAXPAS SM000430
C 101 FORMAT(F9.3,3F10.3,3I5,/,4F10.3,I5) SM000440
C ISIZE = 64 SM000450
C JSIZE = 64 SM000460
C NTIMES = 64 SM000470
C ISCALE=(FLOAT(ISIZE-1))/(MAXLAT-MINLAT) SM000480
C JSCALE=(FLOAT(JSIZE-1))/(MAXLNG-MINLNG) SM000490

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C	===== READ IN LOW DENSITY MAP DATA =====	SM000500
C		SM000510
	CALL IN(XLAT,XLONG,TMAX,TMIN,PREC,L,MAXLAT,MINLAT,MAXLNG,MINLNG)	SM000520
	DO 104 I=1,NTIMES	SM000530
	DO 104 J=1,NTIMES	SM000540
104	P(I,J)=0.0	SM000550
	DO 102 M=1,L	SM000560
	XI=(MAXLAT-XLAT(M))*ISCALE+1	SM000570
	XJ=(MAXLNG-XLONG(M))*JSCALE+1	SM000580
	I=XI	SM000590
	IF (XI-FLOAT(I).GE.0.5) I=I+1	SM000600
	J=XJ	SM000610
	IF (XJ-FLOAT(J).GE.0.5) J=J+1	SM000620
	IF (K.EQ.2) P(I,J)=TMAX(M)	SM000630
	IF (K.EQ.0) P(I,J)=TMIN(M)	SM000640
102	IF (K.EQ.1) P(I,J)=PREC(M)	SM000650
C		SM000660
C	===== WRITE FIELD, DO OBJECTIVE ANALYSIS, PRINTOUT CONTOURED RESULTS =====	SM000670
C		SM000680
	WRITE(6,3)	SM000690
3	FORMAT(1H1,'64 X 64 GRID')	SM000700
	WRITE (6,2) ((P(I,J),J=1,16),I=1,NTIMES)	SM000710
	WRITE (6,2) ((P(I,J),J=17,NTIMES),I=1,NTIMES)	SM000720
2	FORMAT (32(16(1X,F7.3),/))	SM000730
	CALL ANAL(ISIZE,JSIZE,AA,ALF2,ALF4,MAXPAS,ERR,P,U)	SM000740
	WRITE(6,3)	SM000750
	WRITE (6,2) ((U(I,J),J=1,16),I=1,NTIMES)	SM000760
	WRITE (6,2) ((U(I,J),J=17,NTIMES),I=1,NTIMES)	SM000770
	DO 9999 I=1,64	SM000780
	DO 9999 J=1,64	SM000790
	DIFF(I,J)=P(I,J)-U(I,J)	SM000800
9999	IF (P(I,J).EQ.0.0) DIFF(I,J)=0.0	SM000810
	WRITE (6,3)	SM000820
	WRITE (6,2) ((DIFF(I,J),J=1,16),I=1,NTIMES)	SM000830
	WRITE (6,2) ((DIFF(I,J),J=17,NTIMES),I=1,NTIMES)	SM000840
	WRITE (16, 4)	SM000850
4	FORMAT('GRID SMOOTHED, ANALYSIS BEGUN ')	SM000860
	MIN = 0	SM000870
	INT = 0	SM000880
	SCALE = 0.0	SM000890
	CALL BONTUR (P,ISIZE,JSIZE,MIN,INT,SCALE)	SM000900
	MIN = 0	SM000910
	INT = 1	SM000920
	SCALE = 1.0	SM000930
	CALL BONTUR (U,ISIZE,JSIZE,MIN,INT,SCALE)	SM000940
C		SM000950
C	===== BEGINNING OF READ HIGH DENSITY MAP DATA =====	SM000960
C		SM000970
	DO 609 JJJ=1,JSIZE	SM000980
	DO 609 III=1,ISIZE	SM000990
609	P(III,JJJ)=-1.0	SM001000
	CALL IN(XLAT,XLONG,TMAX,TMIN,PREC,L,MAXLAT,MINLAT, *MAXLNG,MINLNG)	SM001010
		SM001020
		SM001030

IF (L.LT.5) GO TO 503	SMO01040
DO 502 M=1,L	SMO01050
XI=(MAXLAT-XLAT(M))*ISCALE+1	SMO01060
XJ=(MAXLNG-XLONG(M))*JSCALE+1	SMO01070
I=XI	SMO01080
IF (XI-FLOAT(I).GE.0.50) I=I+1	SMO01090
J=XJ	SMO01100
IF(XJ-FLOAT(I).GE.0.5) J=J+1	SMO01110
IF (K.EQ.2) P(I,J)=TMAX(M)	SMO01120
IF (K.EQ.0) P(I,J)=TMIN(M)	SMO01130
502 IF (K.EQ.1) P(I,J)=PREC(M)	SMO01140
503 CONTINUE	SMO01150
C	SMO01160
C==== BEGINNING OF INTEGRATION OVER A POLYGON ON THE MAP =====	SMO01170
C	SMO01180
READ (5,108,END=9200) IPOLY	SMO01190
DO 268 INUM=1,IPOLY	SMO01200
IBUF(2)=INUM	SMO01210
READ (5,108,END=9200) L,IDEBUG	SMO01220
108 FORMAT (2I2)	SMO01230
NO=1+L*2	SMO01240
M=3	SMO01250
702 READ (5,100,END=9200) XLAT(M),XLONG(M)	SMO01260
100 FORMAT (F9.3,4F10.3,A5)	SMO01270
XI=(MAXLAT-XLAT(M))*ISCALE+1	SMO01280
XJ=(MAXLNG-XLONG(M))*JSCALE+1	SMO01290
I=XI	SMO01300
J=XJ	SMO01310
IF (XI-FLOAT(I).GE.0.5) I=I+1	SMO01320
IF (XJ-FLOAT(J).GE.0.5) J=J+1	SMO01330
IBUF(M)=J	SMO01340
IBUF(M+1)=I	SMO01350
IF (M.EQ.3) GO TO 703	SMO01360
IF (IBUF(M).NE.IBUF(M-2).OR.IBUF(M+1).NE.IBUF(M-1)) GO TO 703	SMO01370
M=M-2	SMO01380
NO=NO-2	SMO01390
703 IF (M.GE.NO) GO TO 701	SMO01400
M=M+2	SMO01410
GO TO 702	SMO01420
701 CALL POLYG(NO,IBUF,IDEBUG,IX6,J,IYMIN,IYMAX)	SMO01430
C	SMO01440
C==== PAINTING OF INTERIOR OF POLYGON WILL COMMENCE =====	SMO01450
C	SMO01460
I=IYMIN	SMO01470
SUM=0.0	SMO01480
ICNT=0	SMO01490
SS=0.0	SMO01500
SS1=0.0	SMO01510
ICOUNT=0	SMO01520
K=1	SMO01530
206 CONTINUE	SMO01540
K1=IX6(K)	SMO01550
IF (IX6(K).GT.5000) K1=K1-5000	SMO01560
K2=IX6(K+1)	SMO01570
IF(K2.GT.JSIZE) WRITE (16,285)	SMO01580

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286 FORMAT (' POLYGON EXTENDS OUTSIDE OBJECTIVE FIELD IN LONGITUDE ') SMO01590
    IF (K2.GT.JSIZE) CALL EXIT SMO01600
    DO 107 JJ=K1,K2 SMO01610
    ICOUNT=ICOUNT+1 SMO01620
    IF(L.LT.5) GO TO 107 SMO01630
    IF(P(I,JJ).LT.-1.0E-10) GO TO 107 SMO01640
    ICNT=ICNT+1 SMO01650
    SS=SS+U(I,JJ)-P(I,JJ) SMO01660
    SS1=SS1+(U(I,JJ)-P(I,JJ))**2 SMO01670
107 SUM=SUM+U(I,JJ) SMO01680
    IF(I.GT.ISIZE) WRITE (16,296) SMO01690
296 FORMAT (' POLYGON EXTENDS OUTSIDE OBJECTIVE FIELD IN LATITUDE ') SMO01700
    IF (I.GT.ISIZE) CALL EXIT SMO01710
    IF (IX6(K+2).GT.5000) I=I+1 SMO01720
    K=K+2 SMO01730
    IF(K.LT.J) GO TO 206 SMO01740
    SUM=SUM/FLOAT(ICOUNT) SMO01750
    WRITE(7,267) IBUF(2),SUM,ICNT SMO01760
267 FORMAT (' AVERAGE OVER AREA ',I4,' EQUALS ',F9.5,2X, SMO01770
    *'NUMBER OF OBS=',I5) SMO01780
    IF(L.LT. 5) GO TO 268 SMO01790
    SM=SS/(FLOAT(ICNT)) SMO01800
    WRITE (7,362) SM SMO01810
362 FORMAT (' SAMPLE BIAS = ', F9.5) SMO01820
    SM=DSQRT((SS1-(SS**2)/(DFLOAT(ICNT)))/(DFLOAT(ICNT-1))) SMO01830
    SS1=SS1/(FLOAT(ICNT)) SMO01840
    WRITE (7,363) SM,SS1 SMO01850
363 FORMAT (' STANDARD DEVIATION = ', F9.5, ' MSE = ', F10.5,/) SMO01860
268 CONTINUE SMO01870
    IF (L.LT.5) GO TO 5 SMO01880
    GO TO 5 SMO01890
9200 STOP SMO01900
    END SMO01910
    SUBROUTINE IN(XLAT,XLONG,TMAX,TMIN,PREC,L,MAXLAT,MINLAT, SMO01920
    *MAXLNG,MINLNG) SMO01930
    IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R) SMO01940
    REAL*8 XLAT(500),XLONG(500),TMAX(500),TMIN(500),PREC(500) SMO01950
    REAL*8 MAXLAT,MINLAT,MAXLNG,MINLNG SMO01960
    L=0 SMO01970
    ! L=L+1 SMO01980
    READ(5,100,END=9200)XLAT(L),XLONG(L),TMAX(L),TMIN(L),PREC(L),AAA, SMO01990
    * AAB SMO02000
100 FORMAT (F8.3,4F10.3,2A4) SMO02010
    IF (XLAT(L).LT.-90.0) GO TO 40 SMO02020
    ITEST=0 SMO02030
    IF (XLAT(L).GT.MAXLAT.OR.XLAT(L).LT.MINLAT.OR.XLONG(L).GT.MAXLNG SMO02040
    1.OR.XLONG(L).LT.MINLNG) ITEST=1 SMO02050
    IF (ITEST.EQ.1) L=L-1 SMO02060
    GO TO 1 SMO02070
40 CONTINUE SMO02080
    L=L-1 SMO02090
    WRITE (7,106) L SMO02100
106 FORMAT (' NUMBER OF STATIONS READ IN = ',I10,/) SMO02110
9200 RETURN SMO02120
    END SMO02130

```

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C SMS00010
C=====SMS00020
C SMS00030
C POLYG FORTRAN SMS00040
C WRITTEN BY DAVE PITTS (J.S.C.) SMS00050
C MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80 SMS00060
C SMS00070
C POLYG IS A SUBROUTINE TO THE MAINV WEATHER DATA SMOOTHING SMS00080
C ALGORITHM SMS00090
C SMS00100
C=====SMS00110
C SMS00120
C VARIABLES SMS00130
C SMS00140
C NO LENGTH OF INPUT, BUF SMS00150
C BUF INPUT DATA STRING SMS00160
C X6 OUTPUT STRING SMS00170
C J LENGTH OF OUPUT, X6 SMS00180
C BUF(1) UNUSED SMS00190
C BUF(2) NUMBER IDENTIFYING CRD OR PSEUDOZONE SMS00200
C SMS00210
C NO = 1 + L * 2 (L = NUMBER OF PAIRS OF DATA POINTS) SMS00220
C IF IDEBUG IS 1 THEN EXTRA DEBUG OUTPUT IS GENERATED SMS00230
C SMS00240
C=====SMS00250
C SMS00260
SUBROUTINE POLYG(INO,IBUF,IDEBUG,IX6,IJ,IYMIN,IYMAX) SMS00270
IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R) SMS00280
INTEGER*4 IBUF(80),IX6(512) SMS00290
COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX, SMS00300
*X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J SMS00310
NPRT=16 SMS00320
NO=INO SMS00330
DO 30 I=1,80 SMS00340
30 BUF(I)=IBUF(I) SMS00350
102 FORMAT (2I4) SMS00360
CALL S01(IDEBUG) SMS00370
CALL S12(IDEBUG) SMS00380
CALL S23(IDEBUG) SMS00390
CALL S34(IDEBUG) SMS00400
CALL S45(IDEBUG) SMS00410
CALL S55(IDEBUG) SMS00420
CALL S56(IDEBUG) SMS00430
IJ=J SMS00440
DO 31 I=1,512 SMS00450
31 IX6(I)=X6(I) SMS00460
IYMIN=YMIN SMS00470
IYMAX=YMAX SMS00480
RETURN SMS00490
END SMS00500

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C=====SMS00510
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C=====SMS01010

```

S01 FORTRAN
 WRITTEN BY DAVE PITTS (J.S.C.)
 MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80

S01 IS A SUBROUTINE IN THE MAINV WEATHER SMOOTHING ALGORITHM

DEBUG SHOULD BE SET TO 1 TO GET EXTRA PRINTOUT OF WORKING ARRAYS
 INPUT IS THRU DATA STRING BUF CONTAINING X AND Y COORDINATES
 READS BUF INTO X1 AND Y1 AND FINDS YMIN AND YMAX
 BUF(I) CONTAINS X(I) IN ODD I STARTING WITH 3
 THE FOLLOWING IS AN EXAMPLE RUN WITH INPUT

```

1 3
2 1
4 3
6 1
5 6

```

WITH OUTPUT AS FOLLOWS (FIRST LINE IS FOR YMIN)
 (LAST LINE IS FOR YMAX)

```

5002 2 6 6
5002 3 5 6
5001 4 4 6
5002 5
5004 5
5005 5

```

BUF(I) CONTAINS Y(I) IN EVEN I STARTING WITH 4, X(3),Y(4) IS A
 PAIR, BUF(2) IS A FIELD OR PSEUDOZONE NUMBER, BUF(1) IS BLANK.
 OUTPUT IS A DATA STRING X6 FROM SUBROUTINE S56
 TYPICAL CALLING ROUTINE IS AS FOLLOWS

```

CALL S01
CALL S12
CALL S23
CALL S34
CALL S45
CALL S55
CALL S56

```

BUF AND X6 ARE IMPLICIT INTEGERS

```

SUBROUTINE S01(DEBUG)
IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R)
COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
*X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
YMIN=10000
YMAX=-10000
J=1

```


DO 1 I=3,N0,2	SMS01020
X=BUF(I)	SMS01030
Y=BUF(I+1)	SMS01040
IF (Y.LT. YMIN) YMIN=Y	SMS01050
IF (Y.GT. YMAX) YMAX=Y	SMS01060
J=J+1	SMS01070
X1(J)=X	SMS01080
1 Y1(J)=Y	SMS01090
N1=J	SMS01100
C	SMS01110
C===== MAKE OUTLINE OVERLAP AT BOTH ENDS =====	SMS01120
C	SMS01130
X1(1)=X1(J)	SMS01140
Y1(1)=Y1(J)	SMS01150
J=J+1	SMS01160
X1(J)=X1(2)	SMS01170
Y1(J)=Y1(2)	SMS01180
IF (J.GT.50) WRITE (16,102) BUF(2)	SMS01190
102 FORMAT (' FIELD ',I5,' EXCEEDS THE SIZE ALLOWED FOR X1 AND Y1')	SMS01200
RETURN	SMS01210
END	SMS01220

```

C
C=====SMS01230
C
C
C      S12 FORTRAN
C      WRITTEN BY DAVE PITTS (J.S.C.)
C      MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80
C
C      S12 FORTRAN IS PART OF MAINV WEATHER DATA SMOOTHING ALGORITHM,
C      S12 REMOVES REDUNDANT POINTS FROM X1 AND Y1 SO THAT THERE ARE
C      AT MOST 2 CONTIGUOUS POINTS ON A LINE.
C=====SMS01240
C
C      SUBROUTINE S12(DEBUG)
C      IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R)
C      COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
C      *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
C      J=1
C      DO 1 I=2,N1
C      IF (Y1(I).NE.Y1(I-1)) GO TO 2
C      IF (Y1(I).NE.Y1(I+1)) GO TO 2
C
C===== POINT I IS A REDUNDANT POINT =====
C
C      GO TO 1
C      2 CONTINUE
C
C===== POINT IS NOT A REDUNDANT POINT =====
C
C      J=J+1
C      X2(J)=X1(I)
C      Y2(J)=Y1(I)
C      1 CONTINUE
C      N2=J
C
C===== MAKE OUTLINE OVERLAP AT BOTH ENDS =====
C
C      X2(1)=X2(J)
C      Y2(1)=Y2(J)
C      J=J+1
C      X2(J)=X2(2)
C      Y2(J)=Y2(2)
C      J=J+1
C      X2(J)=X2(3)
C      Y2(J)=Y2(3)
C      IF(J.GT.55) WRITE (NPRT,102) BUF(2)
102 FORMAT (' FIELD ',I5,' EXCEEDS THE SIZE ALLOWED FOR X2 AND Y2')
C      RETURN
C      END

```

```

C SMS01720
C=====SMS01730
C SMS01740
C S23 FORTRAN SMS01750
C WRITTEN BY D/VE PITTS (J.S.C.) SMS01760
C MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80 SMS01770
C SMS01780
C S23 IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHM, S23 SMS01790
C INSERTS REDUNDANT POINTS AT MAXIMA, MINIMA, AND INFLECTION POINTS SMS01800
C SMS01810
C=====SMS01820
C SMS01830
C SUBROUTINE S23(DEBUG) SMS01840
C IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R) SMS01850
C COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX, SMS01860
C *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J SMS01870
C J=0 SMS01880
C DO 1 I=2,N2 SMS01890
C YY1=Y2(I-1) SMS01900
C YY2=Y2(I) SMS01910
C YY3=Y2(I+1) SMS01920
C YY4=Y2(I+2) SMS01930
C D12=YY2-YY1 SMS01940
C D23=YY3-YY2 SMS01950
C SMS01960
C==== CHECK TO SEE IF POINTS I AND (I+1) ARE POINTS OF INFLECTION =====SMS01970
C SMS01980
C IF(D23.EQ.0) GO TO 2 SMS01990
C SMS02000
C==== CHECK TO SEE IF POINTS I AND (I-1) ARE A TWO-POINT MAX OR MIN =====SMS02010
C SMS02020
C IF(D12.EQ.0) GO TO 3 SMS02030
C SMS02040
C==== CHECK TO SEE IF POINTS I AND (I-1) ARE A ONE-POINT MAX OR MIN =====SMS02050
C SMS02060
C IF ((D12.GT.0).AND.(D23.GT.0)) GO TO 3 SMS02070
C IF((D12.LT.0).AND.(D23.LT.0)) GO TO 3 SMS02080
C SMS02090
C==== POINT I AIS A MAXIMUM OR MINIMUM =====SMS02100
C SMS02110
C J=J+1 SMS02120
C X3(J)=X2(I) SMS02130
C Y3(J)=Y2(I) SMS02140
C GO TO 3 SMS02150
C 2 CONTINUE SMS02160
C SMS02170
C==== POINTS I AND (I+1) MIGHT BE POINTS OF INFLECTION =====SMS02180
C SMS02190
C D34=YY4-YY3 SMS02200
C IF((D12.GT.0).AND.(D34.LT.0)) GO TO 3 SMS02210
C IF((D12.LT.0).AND.(D34.GT.0)) GO TO 3 SMS02220

```

```

C                                                    SMS02230
C===== POINTS I AND (I+1) ARE POINTS OF INFLECTION =====SMS02240
C                                                    SMS02250
      J=J+1                                           SMS02260
      Y3(J)=Y2(I)                                     SMS02270
      IF(X2(I+1).LT.X2(I)) GO TO 4                  SMS02280
C                                                    SMS02290
C===== PUT A REDUNDANT POINT TO RIGHT OF POINT I AND TAG BY ADDING 5000 =SMS02300
C                                                    SMS02310
      X3(J)=X2(I)+5001                               SMS02320
      GO TO 3                                         SMS02330
      4 CONTINUE                                     SMS02340
C                                                    SMS02350
C===== PUT A REDUNDANT POINT TO LEFT OF POINT I AND TAG BY ADDING 5000 ==SMS02360
C                                                    SMS02370
      X3(J)=X2(I)+4999                               SMS02380
      3 CONTINUE                                     SMS02390
      J=J+1                                           SMS02400
      X3(J)=X2(I)                                     SMS02410
      Y3(J)=Y2(I)                                     SMS02420
      1 CONTINUE                                     SMS02430
      J=J+1                                           SMS02440
      X3(J)=X3(1)                                     SMS02450
      Y3(J)=Y3(1)                                     SMS02460
      N3=J                                             SMS02470
      IF (J.GT.70) WRITE (NPRT,102) BUF(2)          SMS02480
102 FORMAT (' FIELD ',I5,' EXCEEDS THE SIZE ALLOWED FOR X3 AND Y3')SMS02490
      RETURN                                         SMS02500
      END                                           SMS02510

```

```

C SMS02520
C=====SMS02530
C SMS02540
C S34 FORTRAN SMS02550
C WRITTEN BY DAVE PITTS (J.S.C.) SMS02560
C MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80 SMS02570
C SMS02580
C S34 IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHM, S34 SMS02590
C FILLS IN MISSING LINES IN THE DATA SET SMS02600
C SMS02610
C=====SMS02620
C SMS02630
SUBROUTINE S34(DEBUG) SMS02640
IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R) SMS02650
COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX, SMS02660
*X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J SMS02670
N3=N3-1 SMS02680
J=0 SMS02690
DO 1 I=1,N3 SMS02700
XB=X3(I) SMS02710
YB=Y3(I) SMS02720
XN=X3(I+1) SMS02730
YN=Y3(I+1) SMS02740
J=J+1 SMS02750
X4(J)=XB SMS02760
Y4(J)=YB SMS02770
INC=YN-YB SMS02780
IF(INC.EQ.0) GO TO 1 SMS02790
C SMS02800
C=====SMS02810
C SMS02820
C MISSING LINES MUST BE FILLED IN. SMS02830
C CHECK TO SEE IF EITHER I OR (I+1) HAS BEEN TAGGED AS POINT OF SMS02840
C INFLECTION. SMS02850
C SMS02860
C=====SMS02870
C SMS02880
IF(XB.GT.3000) XB=XB-5000 SMS02890
IF(XN.GT.3000) XN=XN-5000 SMS02900
RDX=DFLOAT(XN-XB) SMS02910
RDY=DFLOAT(YN-YB) SMS02920
RS=RDX/RDY SMS02930
RXB=DFLOAT(XB)+0.5 SMS02940
INC=1 SMS02950
IF(RDY.LT.0.0) INC=-1 SMS02960
Y=YB SMS02970
C==== FILL IN LINES BETWEEN (BUT NOT INCLUDING) POINTS I AND (I+1) ====SMS02980
C SMS02990
3 CONTINUE SMS03000

```

J=J+1	SMS03010
Y=Y+INC	SMS03020
RY=DFLOAT(Y-YB)	SMS03030
RX=RXB+RS*RY	SMS03040
X4(J)=RX	SMS03050
Y4(J)=Y	SMS03060
IF(Y.NE.YN) GO TO 3	SMS03070
J=J-1	SMS03080
1 CONTINUE	SMS03090
N4=J	SMS03100
IF(J.GT.511) WRITE (NPRT,102) BUF(2)	SMS03110
102 FORMAT(' FIELD ',I5,' EXCEEDS THE SIZE ALLOWED FOR X4 AND Y4')	SMS03120
RETURN	SMS03130
END	SMS03140

```

C SMS03150
C-----SMS03160
C SMS03170
C S45 FORTRAN SMS03180
C WRITTEN BY DAVE PITTS (J.S.C.) SMS03190
C MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80 SMS03200
C SMS03210
C S34 IS PART OF THE MAIV WEATHER DATA SMOOTHING ALGORITHM, S45 SMS03220
C COLLECTS ALL OF THE INTERCEPTS WITHIN GIVEN LINES SMS03230
C SMS03240
C-----SMS03250
C SMS03260
SUBROUTINE S45(DEBUG) SMS03270
IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R) SMS03280
COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX, SMS03290
*X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J SMS03300
YOFF=YMIN-1 SMS03310
YEND=YMAX-YOFF SMS03320
IF (YEND.GT.200) WRITE (NPRT,102) BUF(2) SMS03330
102 FORMAT (' FIELD ',I5,' HAS TOO MANY LINES') SMS03340
IF (YEND.GT.200) STOP SMS03350
DO 1 I=1,200 SMS03360
X5(I,11)=0 SMS03370
1 CONTINUE SMS03380
IF (N4.GT.512) WRITE (NPRT,200) N4 SMS03390
200 FORMAT (' N4 = ',I5) SMS03400
IF (N4.GT.512) STOP SMS03410
DO 2 I=1,N4 SMS03420
S=X4(I) SMS03430
L=Y4(I)-YOFF SMS03440
IF (L.GT.200) WRITE (NPRT,201) L SMS03450
201 FORMAT (' L= ',I5) SMS03460
IF (L.GT.200) STOP SMS03470
N=X5(L,11) SMS03480
N=N+1 SMS03490
IF (N.GT.10) WRITE (NPRT,103) L,BUF(2) SMS03500
103 FORMAT (' -LINE ',I5,' OF FIELD ',I5,' HAS TOO MANY INTERSECTIONS SMS03510
*NS ') SMS03520
IF (N.GT.10) STOP SMS03530
X5(L,11) = N SMS03540
X5(L,N)=S SMS03550
2 CONTINUE SMS03560
DO 3 L=1,YEND SMS03570
NEND=X5(L,11) SMS03580
3 CONTINUE SMS03590
RETURN SMS03600
END SMS03610

```

```

C SMS03620
C=====SMS03630
C SMS03640
C S55 FORTRAN SMS03650
C WRITTEN BY DAVE PITTS (J.S.C.) SMS03660
C MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80 SMS03670
C SMS03680
C S55 IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHM, S55 SMS03690
C SORTS THE INTERCEPTS INTO ASCENDING ORDER SMS03700
C SMS03710
C=====SMS03720
C SMS03730
C SUBROUTINE S55(DEBUG) SMS03740
C IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R) SMS03750
C COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX, SMS03760
C *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J SMS03770
C YEND=YMAX-YMIN+1 SMS03780
C DO 1 L=1,YEND SMS03790
C NEND=X5(L,11) SMS03800
C NODD=NEND-2*(NEND/2) SMS03810
C IF (NODD.EQ.0) GO TO 6 SMS03820
C SMS03830
C==== AN ODD NUMBER OF INTERSECTIONS IS NOT PERMITTED =====SMS03840
C SMS03850
C LINE=L+YMIN-1 SMS03860
C 102 FORMAT ( ' ODD NUMBER OF VERTICES ON LINE ',I5,' OF FIELD ',I5) SMS03870
C 6 CONTINUE SMS03880
C DO 2 I=1,NEND SMS03890
C XMIN=30000 SMS03900
C DO 3 J=1,NEND SMS03910
C X=X5(L,J) SMS03920
C SMS03930
C=====SMS03940
C SMS03950
C IF THE POINT HAS BEEN USED BEFORE (AND TAGGED AS 31000) JUMP OVER SMS03960
C IT SMS03970
C SMS03980
C=====SMS03990
C SMS04000
C IF (X.EQ.31000) GO TO 3 SMS04010
C SMS04020
C==== IF THE POINT IS TAGGED AS POINT OF INFLECTION SUBTRACT 5000 =====SMS04030
C SMS04040
C IF (X.GT.3000) X=X-5000 SMS04050
C IF (X.GT.XMIN) GO TO 3 SMS04060
C XMIN=X SMS04070
C JMIN=J SMS04080
C 3 CONTINUE SMS04090
C SMS04100
C==== POINT STORED AT JMIN HAS THE SMALLEST REMAINING X-VALUE =====SMS04110
C SMS04120
C X1(I)=X5(L,JMIN) SMS04130

```


C		SMS04140
C====	TAG POINT AT JMIN AS HAVING BEEN USED =====	SMS04150
C		SMS04160
	X5(L,JMIN)=31000	SMS04170
2	CONTINUE	SMS04180
	DO 4 I=1,NEND	SMS04190
	X=X1(I)	SMS04200
	IF (X.LT.3000) GO TO 5	SMS04210
C		SMS04220
C====	THIS POINT IS A NECESSARY REDUNDANT POINT OF INFLECTION =====	SMS04230
C		SMS04240
	J=I/2	SMS04250
	SW=I-2*J	SMS04260
C		SMS04270
C====	POINT IN EVEN POSITION SHOULD BE MOVED TO RIGHT =====	SMS04280
C		SMS04290
	IF(I.EQ.NEND) GO TO 969	SMS04300
	IF (SW.EQ.0) X5(L,I)=X1(I+1)	SMS04310
C		SMS04320
C====	POINT IN ODD POSITION SHOULD BE MOVED TO LEFT =====	SMS04330
C		SMS04340
	IF(I.EQ.1) GO TO 5	SMS04350
969	IF (SW.NE.0) X5(L,I)=X1(I-1)	SMS04360
	GO TO 4	SMS04370
5	CONTINUE	SMS04380
	X5(L,I)=X1(I)	SMS04390
4	CONTINUE	SMS04400
	DO 970 I=1,NEND	SMS04410
	IF (X5(L,I).EQ.31000) X5(L,I)=X1(I)	SMS04420
	IF (X5(L,I).GT.5000) X5(L,I)=X5(L,I)-5000	SMS04430
970	CONTINUE	SMS04440
1	CONTINUE	SMS04450
	RETURN	SMS04460
	END	SMS04470

C		SMS04480
C	=====	SMS04490
C		SMS04500
C	S56 FORTRAN	SMS04510
C	WRITTEN BY DAVE PITTS (J.S.C.)	SMS04520
C	MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80	SMS04530
C		SMS04540
C	S56 IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHM, S56	SMS04550
C	PACKS THE INTERCEPTS INTO A ONE-DIMENSIONAL BUFFER	SMS04560
C		SMS04570
C	=====	SMS04580
C		SMS04590
	SUBROUTINE S56(DEBUG)	SMS04600
	IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R)	SMS04610
	COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,	SMS04620
	*X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J	SMS04630
	YEND=YMAX-YMIN+1	SMS04640
	J=0	SMS04650
	DO 1 L=1,YEND	SMS04660
C		SMS04670
C	==== TAG THE FIRST X-VALUE IN EACH LINE BY ADDING 5000 =====	SMS04680
C		SMS04690
	X5(L,1)=X5(L,1)+5000	SMS04700
	NEND=X5(L,11)	SMS04710
905	IQEND=NEND-3	SMS04720
	IF (NEND.LT.4) GO TO 903	SMS04730
	DO 902 I=1,IQEND,2	SMS04740
	IF (X5(L,I+1).NE.X5(L,I+2)) GO TO 902	SMS04750
	X5(L,I+1)=X5(L,I+3)	SMS04760
	IBEG=I+2	SMS04770
	IEND=IQEND+1	SMS04780
	NEND=NEND-2	SMS04790
	IF (IBEG.GT.IQEND) GO TO 902	SMS04800
	DO 904 IX=IBEG,IEND	SMS04810
904	X5(L,IX)=X5(L,IX+2)	SMS04820
	GO TO 905	SMS04830
902	CONTINUE	SMS04840
903	CONTINUE	SMS04850
	DO 2 I=1,NEND	SMS04860
	J=J+1	SMS04870
	X6(J)=X5(L,I)	SMS04880
2	CONTINUE	SMS04890
1	CONTINUE	SMS04900
	IF (J.GT.511) WRITE (NPRT,102) BUF(2)	SMS04910
102	FORMAT (' FIELD',2X,I5,' EXCEEDS THE SIZE ALLOWED FOR X6 ')	SMS04920
	N6=J	SMS04930
	X6(512)=N6	SMS04940
	RETURN	SMS04950
	END	SMS04960

```

C
C=====SMS04970
C=====SMS04980
C=====SMS04990
C    BONTUR FORTRAN          SMS05000
C    WRITTEN BY DAVE PITTS (J.S.C.) SMS05010
C    MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80 SMS05020
C                                     SMS05030
C    BONTUR IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHM, SMS05040
C    BONTUR PRINTS A STANDARD NI BY NJ GRID WITH CONTURING BETWEEN SMS05050
C    LINES                    SMS05060
C                               SMS05070
C=====SMS05080
C                               SMS05090
C    VARIABLES              SMS05100
C                               SMS05110
C    MIN                    MINIMUM VALUE SMS05120
C    INT                    CONTOURING INTERVAL SMS05130
C    SCALE                  SCALING FACTOR FOR PRINTING SMS05140
C                               SMS05150
C    IF INT = 0 THEN THERE WILL BE NO CONTOURS OR DATA PRINTED SMS05160
C    IF NJJ IS GREATER THAN 26 2 GRIDS ARE PRINTED; SMS05170
C        FROM 1 TO 26 SMS05180
C        FROM 26 TO NJJ SMS05190
C                               SMS05200
C=====SMS05210
C                               SMS05220
C    SUBROUTINE BONTUR(Z,NI,NJJ,MIN,INT,SCALE) SMS05230
C    IMPLICIT INTEGER*4(I-N), REAL*8(A-H, O-Z) SMS05240
C    INTEGER*4 IZ(64,64) SMS05250
C    INTEGER*4 KALP(16),LINE(127),LIN(27) SMS05260
C    REAL*8 Z(64,64) SMS05270
C    DATA KALP/1H ,1HA,1H ,1HB,1H ,1HC,1H ,1HD,1H ,1HE,1H ,1HF,1H , SMS05280
C    1 1HG,1H ,1HH/ SMS05290
C    LTOT=INT*16 SMS05300
C    NTEMP = NJJ SMS05310
C    NJJ = 51 SMS05320
C    NJ=NJJ SMS05330
C                               SMS05340
C                               SMS05350
C===== 360 =====SMS05360
C                               SMS05370
C    J1=1 SMS05380
C    IF(NJJ.GT.26) NJ=26 SMS05390
C    DO 10 I=1,NI SMS05400
C    DO 10 J=1,NJJ SMS05410
C    10 IZ(I,J)=Z(I,J)*SCALE SMS05420
C    IF (INT) 51,50,51 SMS05430
C    51 NIM=NI-1 SMS05440
C    60 NJM=NJ-J1 SMS05450
C    WRITE(6,910) SMS05460
C    910 FORMAT(1H1) SMS05470
C    NUM=5*NJM+1 SMS05480
C    WRITE(6,900)(IZ(1,J),J=J1,NJ) SMS05490
C    900 FORMAT(3X,26I5)

```

DO 1 IR=2,NI	SMS05500
DO 2 JD=1,2	SMS05510
IF(J1.NE.1) GO TO 20	SMS05520
DO 3 L=1,NJ	SMS05530
3 LIN(L)=((IZ(IR,L)-IZ(IR-1,L))*JD)/3+IZ(IR-1,L)	SMS05540
GO TO 30	SMS05550
20 DO 40 L=26,NJJ	SMS05560
40 LIN(L-25)=((IZ(IR,L)-IZ(IR-1,L))*JD)/3+IZ(IR-1,L)	SMS05570
30 K=1	SMS05580
DO 4 J=1,NJM	SMS05590
LINJ=LIN(J)	SMS05600
LINE(K)=LINJ	SMS05610
NDZ=LIN(J+1)-LINJ	SMS05620
DO 5 L=1,4	SMS05630
K=K+1	SMS05640
5 LINE(K)=(NDZ*L)/5+LINJ	SMS05650
K=K+1	SMS05660
4 CONTINUE	SMS05670
LINE(K)=LIN(NJM+1)	SMS05680
DO 6 L=1,NUM	SMS05690
JDF=LINE(L)-MIN	SMS05700
IF(JDF)8,9,9	SMS05710
8 JDF=JDF-LTOT*((JDF+1)/LTOT-1)	SMS05720
9 J=JDF/INT	SMS05730
IF(J-16)6,26,26	SMS05740
26 J=J-(J/16)*16	SMS05750
6 LINE(L)=KALP(J+1)	SMS05760
WRITE(6, 901) (LINE(L),L=1,NUM)	SMS05770
901 FORMAT(7X,126A1)	SMS05780
2 CONTINUE	SMS05790
WRITE(6,900)(IZ(IR,J),J=J1,NJ)	SMS05800
1 CONTINUE	SMS05810
IF(NJ.NE.NJJ) GO TO 2234	SMS05820
NJJ = NTEMP	SMS05830
RETURN	SMS05840
2234 CONTINUE	SMS05850
NJ=NJJ	SMS05860
J1=26	SMS05870
GO TO 60	SMS05880
50 CONTINUE	SMS05890
IF (NJ.NE.NJJ) GO TO 2235	SMS05900
NJJ = NTEMP	SMS05910
RETURN	SMS05920
2235 CONTINUE	SMS05930
NJ=NJJ	SMS05940
J1=26	SMS05950
GO TO 50	SMS05960
END	SMS05970

```

C
C=====SMS05980
C=====SMS05990
C
C      SMS06000
C      ANAL FORTRAN      SMS06010
C      WRITTEN BY DAVE PITTS (J.S.C.)      SMS06020
C      MODIFIED BY KEVIN MCCULLEN (L.A.R.S.) 06/09/80      SMS06030
C      SMS06040
C      ANAL IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHM, ANAL SMS06050
C      PERFORMS VARIATIONAL ANALYSIS BY THE 'KIT WAGNER 2ND DERIVATIVE SMS06060
C      FILTERING' METHOD.      SMS06070
C      ANAL MINIMIZES THE INTEGRAL...      SMS06080
C      SQUARES OF THE DIFFERENCES + THS SQUARES OF THE GRADIENT*ALF2 +SMS06090
C      THE SQUARES OF THE LAPLACIAN*ALF4      SMS06100
C      SMS06110
C=====SMS06120
C      SMS06130
C      VARIABLES      SMS06140
C      SMS06150
C      UO      INPUT DATA      SMS06160
C      U      ANALYSIS      SMS06170
C      AA      FILTER WEIGHTS (SEE NOTE BELOW)      SMS06180
C      ALF2      FILTER WEIGHT      SMS06190
C      ALF4      FILTER WEIGHT      SMS06200
C      MAXPAS      MAXIMUM NUMBER OF ITERATIONS      SMS06210
C      ERR      APROXIMATION CRITERIA      SMS06220
C      SMS06230
C      ARRAY DIMENSIONS      SMS06240
C      SMS06250
C      U(NI,NJ)      SMS06260
C      UO(NI,NJ)      SMS06270
C      WA(NI,NJ)      SMS06280
C      YA(NI+2,NJ+2)      SMS06290
C      SMS06300
C      NOTE: FOR FILTER WEIGHTS REFERENCE K. WAGNER THESIS      SMS06310
C      SMS06320
C      FOR MESOSCALE ANALYSIS OF MAGNITUDE 10, TYPICAL PARAMETERS ARE:      SMS06330
C      AA = 100.0      SMS06340
C      ALF2 = 1.0      SMS06350
C      ALF4 = 1.0      SMS06360
C      MAXPAS = 99      SMS06370
C      ERR = .01      SMS06380
C      SMS06390
C      INCREASING ALF2 AND/OR ALF4 REDUCES HIGHER FREQUENCIES      SMS06400
C      TYPICAL MAXIMUMS ARE:      SMS06410
C      ALF2 = 10.0      SMS06420
C      ALF4 = 10.0      SMS06430
C      AA = 100.0      SMS06440
C      VALUES FOR ALF2 AND ALF4 ARE USUALLY .1, 1.0, 10.0      SMS06450
C      SMS06460
C=====SMS06470
C      SMS06480

```

SUBROUTINE ANAL(NI,NJ,AA,ALF2,ALF4,MAXPAS,ERR,UO,U)	SMS06490
IMPLICIT INTEGER*4 (I-N), REAL*8 (A-H,O-Z)	SMS06500
DIMENSION U(NI,NJ),UO(NI,NJ),YA(66,66),WA(66,66)	SMS06510
EQUIVALENCE (YA(1,1),WA(1,1))	SMS06520
IO=16	SMS06530
NJP2=NJ+2	SMS06540
NIP2=NI+2	SMS06550
NIM1=NI-1	SMS06560
NIM2=NI-2	SMS06570
NJM1=NJ-1	SMS06580
NJM2=NJ-2	SMS06590
NJP1=NJ+1	SMS06600
NIP1=NI+1	SMS06610
BETA=2.0	SMS06620
C	SMS06630
C==== INITIALIZE GUESS FIELD BY AVERAGING =====	SMS06640
C	SMS06650
DO 16 J=1,NJ	SMS06660
DO 16 I=1,NI	SMS06670
16 U(I,J)=UO(I,J)	SMS06680
DO 10 J=1,NJP2	SMS06690
DO 10 I=1,NIP2	SMS06700
10 YA(I,J)=0.0	SMS06710
DO 9997 J=1,NJ	SMS06720
DO 9997 I=1,NI	SMS06730
IF (U(I,J) .NE. 0) GO TO 9998	SMS06740
9997 CONTINUE	SMS06750
DO 9996 J=1,NJ	SMS06760
DO 9996 I=1,NI	SMS06770
UO(I,J)=0.0	SMS06780
9996 U(I,J)=0.0	SMS06790
RETURN	SMS06800
9998 KNT=1	SMS06810
201 CONTINUE	SMS06820
C	SMS06830
C==== CHECK FOR NUMBER OF NO GUESS =====	SMS06840
C	SMS06850
IF (KNT) 15,200,15	SMS06860
15 KNT=0	SMS06870
DO 12 J=2,NJP1	SMS06880
DO 12 I=2,NIP1	SMS06890
12 YA(I,J)=U(I-1,J-1)	SMS06900
DO 99 J=2,NJP1	SMS06910
DO 99 I=2,NIP1	SMS06920
IF (YA(I,J)) 86,98,86	SMS06930
98 SUM=0.0	SMS06940
CNT=0.0	SMS06950
C	SMS06960
C==== AVERAGE NINE POINTS =====	SMS06970
C	SMS06980

```

24 DO 97 JK=1,3                      SMS06990
    DO 97 IK=1,3                      SMS07000
    II=I-2+IK                        SMS07010
    JJ=J-2+JK                        SMS07020
    IF (YA(II,JJ)) 96,97,96          SMS07030
96 SUM=SUM+YA(II,JJ)                 SMS07040
    CNT=CNT+1.                       SMS07050
97 CONTINUE                          SMS07060
    IF (CNT) 93,92,93                SMS07070
93 IF (SUM) 95,94,95                 SMS07080
C                                     SMS07090
C=== USE .0001 INSTEAD OF ZERO AVERAGE ===== SMS07100
C                                     SMS07110
94 U(I-1,J-1)=.0001                 SMS07120
    GO TO 99                         SMS07130
95 U(I-1,J-1)=SUM/CNT               SMS07140
    GO TO 99                         SMS07150
92 KNT=KNT+1                        SMS07160
    GO TO 99                         SMS07170
86 U(I-1,J-1)=YA(I,J)              SMS07180
99 CONTINUE                         SMS07190
200 CONTINUE                        SMS07200
    WRITE(IO,100) KNT                SMS07210
100 FORMAT(I5,29H POINTS UNSPECIFIED THIS PASS) SMS07220
    IF (KNT) 201,79,201              SMS07230
79 CONTINUE                         SMS07240
C                                     SMS07250
C=== SMOOTH FIELD OF AVERAGES ===== SMS07260
C                                     SMS07270
    DO 31 J=2,NJM1                  SMS07280
    DO 31 I=2,NIM1                  SMS07290
31 WA(I,J)=(4.*U(I,J)+U(I-1,J-1)+U(I+1,J-1)+U(I+1,J+1)+U(I-1,J+1) SMS07300
    1+2.*(U(I,J-1)+U(I+1,J)+U(I,J+1)+U(I-1,J)))/16. SMS07310
    DO 32 J=2,NJM1                  SMS07320
    WA(1,J)=(8.*U(1,J)+2.*(U(2,J)+U(1,J-1)+U(1,J+1))+U(2,J-1)+U(2,J+1 SMS07330
    1))/16.                          SMS07340
32 WA(NI,J)=(8.*U(NI,J)+2.*(U(NIM1,J)+U(NI,J-1)+U(NI,J+1))+U(NIM1,J-1 SMS07350
    1)+U(NIM1,J+1))/16.              SMS07360
    DO 33 I=2,NIM1                  SMS07370
    WA(I,1)=(8.*U(I,1)+2.*(U(I,2)+U(I-1,1)+U(I+1,1))+U(I-1,2)+U(I+1,2 SMS07380
    1))/16.                          SMS07390
33 WA(I,NJ)=(8.*U(I,NJ)+2.*(U(I,NJM1)+U(I-1,NJ)+U(I+1,NJ))+U(I-1,NJM1 SMS07400
    1)+U(I+1,NJM1))/16.              SMS07410
    WA(1,NJ)=(3.*U(1,NJ)+2.*(U(2,NJ)+U(1,NJM1))+U(2,NJM1))/8. SMS07420
    WA(NI,NJ)=(3.*U(NI,NJ)+2.*(U(NIM1,NJ)+U(NI,NJM1))+U(NIM1,NJM1))/8. SMS07430
    WA(NI,1)=(3.*U(NI,1)+2.*(U(NIM1,1)+U(NI,2))+U(NIM1,2))/8. SMS07440
    WA(1,1)=(3.*U(1,1)+2.*(U(2,1)+U(1,2))+U(2,2))/8. SMS07450
    DO 36 J=1,NJ                    SMS07460
    DO 36 I=1,NI                     SMS07470
36 U(I,J)=WA(I,J)                   SMS07480
39 CONTINUE                         SMS07490

```

```

C
C===== 2 DIMENSIONAL ANALYSIS OF INTERIOR POINTS AND WEIGHTS =====
C
GRD=(NI-4)*(NJ-4)
ALF4B=ALF4*BE/A
UIJO=4.*ALF2+20.*ALF4
UI1J1=-ALF2-8.*ALF4
WRITE(7,500) AA,ALF2,ALF4,UIJO,UI1J1
C
C===== ITERATIVE SCHEME =====
C
DO 41 IT=1,MAXPAS
IA=1
SUM=0.0
DO 42 J=3,NJM2
DO 42 I=3,NIM2
UIJ=UIJO
C
C===== CHECK FOR OBSERVATION =====
C
IF (UO(I,J)) 43,44,43
44 AL=0.0
GO TO 45
43 AL=AA
UIJ=UIJ+AL
C
C===== EQUATION FOR RESIDUAL =====
C
45 RES=-AL*UO(I,J)+UIJ*U(I,J)+UI1J1*(U(I+1,J)+U(I-1,J)+U(I,J+1)+U(I,J-1))+ALF4B*(U(I-1,J-1)+U(I-1,J+1)+U(I+1,J-1)+U(I+1,J+1))
RES=RES+ALF4*(U(I,J+2)+U(I,J-2)+U(I+2,J)+U(I-2,J))
RLAXP=1./UIJ
C
C===== CORRECT GUESS OF U =====
C
U(I,J)=U(I,J)-RLAXP*RES
C
C===== CHECK FOR APPROXIMATION SATISFIED AT ALL POINTS =====
C
IF (DABS(RES)-ERR) 46,46,47
47 IA=2
46 SUM=SUM+RES*RES
42 CONTINUE
STD=DSQRT(SUM/GRD)
GO TO (41,41),IA
41 CONTINUE
WRITE (7,510)IT,STD
9 WRITE(7,511) IT
510 FORMAT(1X,I3,E12.5)
511 FORMAT(1X,17HNO. OF ITERATIONS,I5)
500 FORMAT(8H WEIGHTS/5E15.2/28H STD DEVIATION OF RESIDUAL )
RETURN
END

```


Appendix B. Listing of SAS programs which carried out the estimation of yield and yield variances for corn and soybeans. The programs given are for the county level. Other levels were estimated in a similar manner. An example program for computation of covariances is also given.

```

* SAS PROGRAM FOR CORN YIELD ESTIMATION FOR EACH COUNTY IN IOWA.
* BASED ON A USDA YIELD MODEL, WHICH USES LINEAR REGRESSION TECHNIQUES
* AND METEOROLOGICAL PREDICTOR VARIABLES.
* PROGRAM IS USED TO PREDICT 1978 YIELDS WITH A MODEL DEVELOPED USING
* YIELD DATA FROM 1932 TO 1977, AND MET DATA FROM 1932 TO 1978.
* WRITTEN BY CAROL JOBUSCH AT LARS, 1981.
* ;
DATA YLDMET; SET METCROP2. CTY ;
  DROP SACRES SPROD SYIELD;
  IF STRATUM = QQ
  CYLD = CYIELD;
  IF YEAR = 70 OR YEAR = 78 THEN CYLD = . ;
  TREND1=0; TREND2=0;
  IF YEAR > 40 THEN TREND1=YEAR-40;
  IF YEAR > 60 THEN TREND1=20;
  IF YEAR > 60 THEN TREND2=YEAR-60;
  IF YEAR > 72 THEN TREND2=12;
  PCP_TMP5=PCP5*TMP5;
  PCP_TMP6=PCP6*TMP6;
  JUN_T_SQ=TMP6*TMP6;
  JUL_P=PCP7;
  JUL_T_SQ=JUL T DT*JUL T DT;
  LABEL TREND1=LINEAR TREND 1941-1960;
  LABEL TREND2=LINEAR TREND 1961-1972;
  LABEL PCP_TMP5=MAY TEMP*PRECIP INTERACTION;
  LABEL PCP_TMP6 = JUNE TEMP*PRECIP INTERACTION;
  LABEL JUN_T_SQ = JUNE TEMP DFN SQUARED;
  LABEL JUL_P = JULY PRECIPITATION DFN;
  LABEL JUL_T_DT = JULY TEMP DEPARTURE FROM TREND;
  LABEL JUL_T_SQ = JULY TEMP DFT SQUARED;
  LABEL AUG_T_DT =AUGUST TEMP DEPARTURE FROM TREND;
PROC REG DATA=YLDMET OUTSSCP=SSYX OUTEST=BLDATA;
  TITLE1 *****;
  TITLE2 ***** IOWA CORN MODEL -- COUNTY QQ *****;
  TITLE3 *****;
  TITLE4 ;
  TITLE5 PREDICTION OF IOWA CORN YIELDS BASED ON 1932-1977 (EXCEPT 1970);
  MODEL CYLD=TREND1 TREND2 PCP_TMP5 PCP_TMP6 JUN_T_SQ JUL_P JUL_T_DT
  JUL_T_SQ AUG_T_DT/ P ;
  OUTPUT OUT=YLDMET PREDICTED=CPYIELD RESIDUAL=CRESID;
PROC PRINT DATA=YLDMET; VAR YEAR CYIELD CPYIELD CRESID;
PROC PLOT DATA=YLDMET;
  TITLE5 'ACTUAL(*) VS PREDICTED(P) CORN YIELDS (1932-78)';
  PLOT CYIELD*YEAR='*' CPYIELD*YEAR='P' / OVERLAY ;
*
* PREPARE TO CALCULATE THE VARIANCE OF THE PREDICTED YIELD FOR 1978
* ;
DATA X78; SET YLDMET;
  KEEP TREND1 TREND2 PCP_TMP5 PCP_TMP6 JUN_T_SQ JUL_P JUL_T_DT JUL_T_SQ
  AUG_T_DT;
  IF YEAR=78;

```

```

DATA VSAVE; SET YLDMET;
  KEEP SYSTEM STRATUM CSIZE CYIELD CPYIELD CACRES CPROD;
  IF YEAR=78;
DATA XPX; SET SSYX;
  IF N =2 THEN DELETE;
PROC MATRIX ;
  TITLE4 *****;
  TITLE5 ***** X'X MATRIX FOR THE 1978 ESTIMATE *****;
  TITLE6 *****;
  TITLE7 *****;
  FETCH XPX DATA=XPX(KEEP=INTERCEP TREND1 TREND2 PCP TMP5 PCP TMP6
    JUN T SQ JUL P JUL T DT JUL T SQ AUG T DT) COLNAME=XNAMES;
  FETCH X78 DATA=X78(KEEP=TREND1 TREND2 PCP TMP5 PCP TMP6 JUN T SQ
    JUL P JUL T DT JUL T SQ AUG T DT) COLNAME=X78NAMES;
  ONE=1;
  X78=ONE || X78;
  NAMEONE = 'INTERCEP' ;
  X78NAMES = NAMEONE || X78NAMES ;
  PE=X78*INV(XPX)*(X78)';
  FETCH SIGMA DATA=BDATA (KEEP=_SIGMA_);
  SIGMASQ = SIGMA*SIGMA ;
  VARCORN = SIGMASQ*PE ;
  IVARCORN = SIGMASQ*(1+PE);
  FETCH VSAVE
    DATA=VSAVE(KEEP=SYSTEM STRATUM CSIZE CYIELD CPYIELD CACRES CPROD)
    COLNAME=VNAMES;
  VSAVE = VSAVE || VARCORN ;
  VSAVE = VSAVE || IVARCORN ;
  NVARCORN = 'VARCORN' 'IVARCORN';
  VNAMES = VNAMES || NVARCORN ;
  PRINT XPX COLNAME=XNAMES ROWNAME=XNAMES;
  PRINT X78 COLNAME=X78NAMES;
  PRINT PE SIGMA ;
  PRINT VSAVE COLNAME=VNAMES;
  OUTPUT VSAVE OUT=SASOUT. CTYQQ COLNAME=VNAMES ;
*
* SAVE RESIDUALS FOR LATER CALCULATION OF THE COVARIANCE OF THE
* PREDICTED YIELD FOR EACH STRATIFICATION SYSTEM.
*
DATA CRESIDX. CTYQQ ; SET YLDMET;
  KEEP SYSTEM STRATUM YEAR CRESID CPYIELD ;

```

```

* SAS PROGRAM FOR SOYBEAN YIELD ESTIMATION FOR EACH COUNTY IN IOWA.
* BASED ON A USDA YIELD MODEL, WHICH USES LINEAR REGRESSION TECHNIQUES
* AND METEOROLOGICAL PREDICTOR VARIABLES.
* PROGRAM IS USED TO PREDICT 1978 YIELDS WITH A MODEL DEVELOPED USING
* YIELD DATA FROM 1932 TO 1977, AND MET DATA FROM 1931 TO 1978.
* WRITTEN BY CAROL JOBUSCH AT LARS, 1981.
* ;
DATA YLDMET; SET METCROP2. CTY ;
  DROP CACRES CPROD CYIELD;
  IF STRATUM = QQ ;
  SYLD = SYIELD;
  IF YEAR = 78 THEN SYLD = . ;
  TREND=YEAR-31;
  IF YEAR > 74 THEN TREND=43;
  PCP_TMP5=PCP5*TMP5;
  AUG_P_SQ=PCP8*PCP8;
  LABEL TREND=LINEAR TREND 1932-1974;
  LABEL CUM_PCP=CUMULATIVE PRECIP OCT-APR DFN;
  LABEL PCP_TMP5=MAY TEMP*PRECIP INTERACTION;
  LABEL TMP6 = JUNE TEMPERATURE DFN;
  LABEL PCP7 =JULY PRECIPITATION DFN;
  LABEL JUL_T_DT = JULY TEMP DEPARTURE FROM TREND;
  LABEL PCP8 = AUGUST PRECIPITATION DFN;
  LABEL AUG_P_SQ = AUGUST PRECIPITATION DFN SQUARED;
  LABEL AUG_T_DT =AUGUST TEMP DEPARTURE FROM TREND;
PROC REG DATA=YLDMET OUTSSCP=SSYX OUTEST=BDATA;
  TITLE1 *****;
  TITLE2 ***** IOWA SOYBEAN MODEL - COUNTY QQ *****;
  TITLE3 *****;
  TITLE4 ;
  TITLE5 BOOTSTRAP TEST FOR THE YEAR 1978;
  MODEL SYLD=TREND CUM_PCP PCP_TMP5 TMP6 PCP7 JUL_T_DT PCP8 AUG_P_SQ
    AUG_T_DT;
  OUTPUT OUT=YLDMET PREDICTED=SPYIELD RESIDUAL=SRESID;
PROC PRINT DATA=YLDMET; VAR YEAR SYIELD SPYIELD ;
  TITLE5 PREDICTION OF IOWA SOYBEAN YIELDS BASED ON YEARS 1932-1977;
PROC PLOT DATA=YLDMET;
  TITLE5 'ACTUAL(*) VS PREDICTED(P) SOYBEAN YIELDS (1932-78)';
  PLOT SYIELD*YEAR='*' SPYIELD*YEAR='P' / OVERLAY ;
*
* PREPARE TO CALCULATE VARIANCE OF THE PREDICTED YIELD FOR 1978.
* ;
DATA X78; SET YLDMET;
  KEEP TREND CUM_PCP PCP_TMP5 TMP6 PCP7 JUL_T_DT PCP8 AUG_P_SQ AUG_T_DT;
  IF YEAR=78;
DATA VSAVE; SET YLDMET;
  KEEP SYSTEM STRATUM SYIELD SPYIELD SACRES SPROD;
  IF YEAR=78;
DATA XPX; SET SSYX;
  IF _N_ =2 THEN DELETE;

```

```

PROC MATRIX ;
TITLE4 *****;
TITLE5 *****;
TITLE6 *****;
TITLE7 *****;
X'X MATRIX FOR THE 1978 ESTIMATE *****;
FETCH XPX DATA=XPX(KEEP=INTERCEP TREND CUM_PCP PCP_TMP5 TMP6 PCP7
JUL_T_DT PCP8 AUG_P_SQ AUG_T_DT) COLNAME=XNAMES;
FETCH X78 DATA=X78(KEEP= TREND_CUM_PCP PCP_TMP5 TMP6 PCP7 JUL_T_DT
PCP8 AUG_P_SQ AUG_T_DT) COLNAME=X78NAMES;
ONE=1;
X78=ONE || X78;
NAMEONE = 'INTERCEP' ;
X78NAMES = NAMEONE || X78NAMES ;
PE=X78*INV(XPX)*(X78)';
FETCH SIGMA DATA=BDATA (KEEP=_SIGMA_);
SIGMASQ = SIGMA*SIGMA ;
VARSOY = PE*SIGMASQ ;
IVARSOY = SIGMASQ*(1+PE) ;
FETCH VSAVE
DATA=VSAVE (KEEP=SYSTEM STRATUM SYIELD SPYIELD SACRES SPROD)
COLNAME=VNAMES;
VSAVE = VSAVE || VARSOY ;
VSAVE = VSAVE || IVARSOY ;
NVARSOY = 'VARSOY' 'IVARSOY';
VNAMES = VNAMES || NVARSOY ;
PRINT XPX COLNAME=XNAMES ROWNAME=XNAMES;
PRINT X78 COLNAME=X78NAMES;
PRINT PE SIGMA ;
PRINT VSAVE COLNAME=VNAMES;
OUTPUT VSAVE OUT=SOYOUT. ZZZ COLNAME=VNAMES ;
*
* SAVE RESIDUALS FOR LATER CALCULATION OF THE COVARIANCE OF THE
* PREDICTED YIELD FOR EACH STRATIFICATION SYSTEM.
*
DATA SRESIDX. CTYQQ ; SET YLDMET;
KEEP SYSTEM STRATUM YEAR SRESID SPYIELD ;

```

```

* SAS PROGRAM TO CALCULATE THE COVARIANCE OF THE YIELD ESTIMATION
* FOR A GIVEN STRATIFICATION SYSTEM.
* THE ACRES OF CORN AND SOYBEANS FOR EACH STRATUM ARE USED AS WEIGHTS.
* WRITTEN BY CAROL JOBUSCH AT LARS, AUGUST 1981.
* ;
DATA WTEMP0; SET METCROP2. XXX ;
  IF YEAR = 78 ;
PROC SUMMARY DATA=WTEMP0 ;
  CLASS STRATUM; VAR CACRES SACRES;
  OUTPUT OUT=WTEMP1 SUM=CACRES SACRES;
DATA WTEMP2; SET WTEMP1; RETAIN CTOT STOT;
  IF TYPE =0 THEN DO;
    CTOT = CACRES; STOT = SACRES; DELETE; END;
  CWT = CACRES/CTOT; SWT = SACRES/STOT; SYSTEM = ZZ ;
  KEEP SYSTEM STRATUM CWT SWT;
PROC SORT DATA=RESID. XXX OUT=TEMP; BY YEAR;
DATA TEMP2;
  KEEP SYSTEM YEAR CRESID1-CRESIDQQ
    SRESID1-SRESIDQQ ;
  ARRAY CRESIDS (STRATUM) CRESID1-CRESIDQQ ;
  ARRAY SRESIDS (STRATUM) SRESID1-SRESIDQQ ;
  DO OVER CRESIDS;
    SET TEMP; BY YEAR;
    CRESIDS = CRESID ;
    SRESIDS = SRESID ;
    IF LAST.YEAR THEN RETURN; END;
  TITLE DATA SET TEMP;
PROC CORR NOCORR COV OUT=CYTEMP (TYPE=COV) DATA=TEMP2;
  VAR CRESID1-CRESIDQQ ;
  TITLE DATA SET CVCORNY. XXX ;
DATA CYTEMP2 (TYPE=COV); SET CYTEMP;
  IF TYPE = 'COV' ;
PROC TRANSPOSE DATA=WTEMP2 OUT=CORNWT PREFIX=CWT; VAR CWT;
PROC MATRIX ;
  FETCH COVM DATA=CYTEMP2 (KEEP=CRESID1-CRESIDQQ ) COLNAME=CNAMES;
  FETCH CWT DATA=CORNWT (KEEP=CWT1-CWTQQ );
  CWTD = DIAG(CWT);
  COVM = CWTD * COVM * CWTD;
  OUTPUT COVM OUT=CYTEMP3 COLNAME=CNAMES;
DATA CYTEMP4; SET CYTEMP3;
  SYSTEM = ZZ ;
DATA CVCORNY. XXX ; SET CYTEMP4; BY SYSTEM;
  KEEP SYSTEM COVCY;
  ARRAY CY(I) CRESID1-CRESIDQQ ;
  I = 1;
  DO WHILE (I LT _N_);
    COVCY + CY;
    I + 1;
  END;
  IF LAST.SYSTEM THEN OUTPUT;
PROC PRINT;

```

```

PROC CORR NOCORR COV OUT=SYTEMP (TYPE=COV) DATA=TEMP2;
  VAR SRESID1-SRESIDQQ ;
  TITLE DATA SET CVSOYY. XXX ;
DATA SYTEMP2; SET SYTEMP;
  IF TYPE = 'COV';
PROC TRANSPOSE DATA=WTEMP2 OUT=SOYWT PREFIX=SWT; VAR SWT;
PROC MATRIX ;
  FETCH COVM DATA=SYTEMP2 (KEEP=SRESID1-SRESIDQQ ) COLNAME=SNAMES;
  FETCH SWT DATA=SOYWT (KEEP=SWT1-SWTQQ );
  SWTD = DIAG(SWT);
  COVM = SWTD * COVM * SWTD;
  OUTPUT COVM OUT=SYTEMP3 COLNAME=SNAMES;
DATA SYTEMP4; SET SYTEMP3;
  SYSTEM = ZZ ;
DATA CVSOYY. XXX ; SET SYTEMP4; BY SYSTEM;
  KEEP SYSTEM COVSY;
  ARRAY SY(I) SRESID1-SRESIDQQ ;
  I = 1;
  DO WHILE (I LT _N_);
    COVSY + SY;
    I + 1;
  END;
  IF LAST.SYSTEM THEN OUTPUT;
PROC PRINT;

```

Appendix C. FORTRAN programs used for estimation of the area variances.
Both the pixel size (msefs3) and the field size (msefs) estimation
programs are presented.

msefs3 fortran

```

IMPLICIT REAL*8 (A-H,O-Z)
REAL*8 Y(100),YP(100),YPC(100),YW(100),
*      E(100),YGPC(100),PE(100),RE(100),Z(100),
*      NEWPC,XXX(100),YYP(100),YAG(100),FLD(100)
INTEGER*4 JCNT(100),STRATM,STRATO,COUNTY,SYSNUM,SNOLD
REAL*8 CTYNAM,CNAME(100)
IEOF=0
I=0
KKK=0
READ(1,100,END=99) SYSTEM,SYSNUM,STRATM,COUNTY,CTYNAM,FLDACR,IGPC,
* IPC,AGRI,CPACRE,CROP
SYSOLD = SYSTEM
SNOLD = SYSNUM
STRATO = STRATM
IF (IPC.NE. 0) GO TO 2
1 READ(1,100,END=99) SYSTEM,SYSNUM,STRATM,COUNTY,CTYNAM,FLDACR,IGPC,
* IPC,AGRI,CPACRE,CROP
100 FORMAT(A8,2I3,I5,1X,A8,F4.0,2I3,2F8.0,2X,A8)
IF(IPC.EQ.0) GO TO 1
IF((SYSNUM.NE.SNOLD).OR.(STRATM.NE.STRATO)) GO TO 3
2 I=I+1
CNAME(I) = CTYNAM
JCNT(I)=COUNTY
Y(I)=CPACRE
YAG(I)=CPACRE/AGRI
YPC(I)=IPC
YGPC(I)=IGPC
FLD(I) = FLDACR
GO TO 1
99 IEOF=1
3 CONTINUE
KKK=KKK+1
IF(I.EQ.1) GO TO 7
SUM=0.0D00
FLDSUM=0.0
SUMPC=0.0D00
SUMGPC=0.0D00
DO 4 J=1,I
IF(YPC(J).GT.0.0) SUM=SUM+Y(J)
SUMPC=SUMPC+YPC(J)
SUMGPC=SUMGPC+YGPC(J)
FLDSUM=FLDSUM+FLD(J)
4 CONTINUE
IF(SUM.EQ.0.0) GO TO 7
P=SUM/(SUMPC*25426.56D00)
DO 55 J=1,I
IF(YPC(J).GT.0.0) YP(J)=Y(J)/(YPC(J)*25426.56D00)
YW(J)=YPC(J)/SUMPC
E(J)=(P-YP(J))**2
55 CONTINUE

```

```

FLDSIZ = FLDSUM/I
A = P * (1.0-P) * 4.0 / 9.0
NN=0
DO 54 J=1,I
IF(YPC(J).EQ.0.0) GO TO 54
NN=NN+1
XXX(NN)=YPC(J)
YYP(NN)=E(J)
54 CONTINUE
WRITE(2,225) CROP,SYSOLD,STRATO
225 FORMAT('1 CROP = ',A8,2X,'SYSTEM = ',A8,2X,'STRATUM = ',I3)
DO 227 J=1,NN
227 XXX(J)=XXX(J)*(25426.0/FLDSIZ)
CALL FITB(NN,XXX,YYP,A,B)
A=A/((FLDSIZ*(22932.0/25426.0))**B)
SF=22932.0D00**B
VAR = A*SF
WRITE(2,200) I,P,A,B,SF,VAR
200 FORMAT('// NUMBER OF COUNTIES IN STRATUM = ',I3/' P = ',F16.9
*   '// A = ',F16.9 /' B = ',F16.9
*   '/ SF = ',F15.9 /' VAR = ',F14.9)
DO 11 J=1,I
IF(YPC(J).GT.0.0) PE(J)=A*(YPC(J)*22932.0D00)**B
IF(YPC(J).EQ.0.0) PE(J)=0.0D00
IF(YPC(J).GT.0.0) RE(J)=(PE(J)-E(J))
IF(YPC(J).EQ.0.0) RE(J)=0.0D00
11 CONTINUE
M=0
X=0.0D00
SX=0.0D00
DO 13 J=1,I
IF(YPC(J).EQ.0.0) GO TO 13
M=M+1
X=X+RE(J)
SX=SX+RE(J)**2
13 CONTINUE
IF(M.GT.1) GO TO 14
WRITE(2,500)
500 FORMAT('/',1X,'DEGREES OF FREEDOM=0',/)
GO TO 7
14 XM=M
SD=SX-X**2/XM
SD=SD/(XM-1.0D00)
SD=DSQRT(SD)
BAR=X/XM
DO 17 J=1,I
IF(YPC(J).GT.0.0) Z(J)=(RE(J)-BAR)/SD
IF(YPC(J).EQ.0.0) Z(J)=0.0D00
17 CONTINUE
WRITE(2,400)
400 FORMAT('/',1X,'CNTY   GPC       PC       ACRES       PI       WI',
*   '      (PI-P)**2   PROJECTED  ERROR      ,
*   '      Z VALUE    CNTY')

```

```

DO 6 J=1,I
WRITE(2,300) JCNT(J),YGPC(J),YPC(J),Y(J),YP(J),YW(J),E(J),
* PE(J),RE(J),Z(J),CNAME(J)
300 FORMAT(1X,I3,2(3X,F4.0),3X,F8.0,2(3X,F7.4),2(3X,F10.7),
1(3X,F10.7),(3X,F10.4),6X,A8)
6 CONTINUE
DO 21 J=1,I
PC=YPC(J)
IF(YAG(J).GE.1.0) GO TO 180
IF((DABS(Z(J)).LE.3.0).OR.(PC.LE.0.0).OR.
* (YPC(J).GT.0.5*YGPC(J))) GO TO 21
YPC(J)=0.0
WRITE(2,700) JCNT(J),Z(J)
700 FORMAT(//,1X,'COUNTY',I5,5X,'REJECTED',5X,'Z=',F10.3)
GO TO 21
180 CONTINUE
YPC(J)=0.0
WRITE(2,780) JCNT(J),YAG(J)
780 FORMAT(//,1X,'COUNTY',I5,5X,'CROP TO AG RATIO=',F10.3)
21 CONTINUE
NEWPC=0.0
DO 22 J=1,I
22 NEWPC=NEWPC+YPC(J)
III=NEWPC
JJJ=SUMPC
WRITE(3,1000) CROP,SYSOLD,STRATO,KKK,SUMGPC,SUMPC,
* A,B,SF,P,VAR,I
1000 FORMAT(2A8,2I3,2F7.0,5F8.4,I4)
IF((III.LT.JJJ).AND.(KKK.LE.3)) GO TO 3
WRITE(4,1000) CROP,SYSOLD,STRATO,KKK,SUMGPC,SUMPC
6,A,B,SF,P,VAR,I
7 CONTINUE
SYSOLD=SYSTEM
SNOLD = SYSNUM
STRATO=STRATM
I=0
KKK=0
IF(IEOF.EQ.0) GO TO 2
STOP
END

```

```

SUBROUTINE FITB(N,X,Y,A,B)
IMPLICIT REAL*8 (A-H,O-Z)
REAL*8 X(100),Y(100),MAX
EPS=0.000001D00
I=0
K=10
XK=X
B1=-0.90
B2=-0.10
WRITE(2,200)
1 CONTINUE
DELTA=(B2-B1)/XK
MAX=F(X,Y,A,B1,N)
DO 9 J=1,K
B=B1+J*DELTA
FB=F(X,Y,A,B,N)
IF(MAX.LT.FB) GO TO 9
MAX=FB
BB=B
9 CONTINUE
I=I+1
WRITE(2,100) I,BB,MAX,DELTA
IF(I.GT.20) GO TO 99
IF(DELTA.LT.EPS) GO TO 99
B1=BB-DELTA
B2=BB+DELTA
GO TO 1
200 FORMAT(/,T6,'K',T23,'B(K)',T41,'F(B(K))',T64,'DELTA')
100 FORMAT(1X,I5,6(1X,F20.15))
99 CONTINUE
B=BB
FB=MAX
RETURN
END

```

```

REAL FUNCTION F*8 (X,Y,A,B,N)
IMPLICIT REAL*8 (A-H,O-Z)
REAL*8 X(100),Y(100),A,B,S,Y1,XB
S=0.0D00
DO 1 J=1,N
XB=1.0
Y1=Y(J)
IF((X(J).EQ.0.0).OR.(B.EQ.0.0)) GO TO 10
XB=X(J)**B
10 S=S+(Y1-A*XB)**2
1 CONTINUE
F=S/N
RETURN
END

```

msefs fortran

```

IMPLICIT REAL*8 (A-H,O-Z)
GENERIC
REAL*8 Y(100),YP(100),YPC(100),YW(100),
*      E(100),YGPC(100),PE(100),RE(100),Z(100),
*      NEWPC,XXX(100),YYF(100),YAG(100),FLD(100)
INTEGER*4 JCNT(100),STRATM,STRATO,COUNTY,SYSNUM,SNOLD
REAL*8 CTYNAM,CNAME(100)
IEOF=0
I=0
KKK=0
READ(1,100,END=99) SYSTEM,SYSNUM,STRATM,COUNTY,CTYNAM,FLDACR,IGPC,
* IPC,AGRI,CPACRE,CROP
SYSOLD = SYSTEM
SNOLD = SYSNUM
STRATO = STRATM
IF (IPC .NE. 0) GO TO 2
1 READ(1,100,END=99) SYSTEM,SYSNUM,STRATM,COUNTY,CTYNAM,FLDACR,IGPC,
* IPC,AGRI,CPACRE,CROP
100 FORMAT(A8,2I3,I5,1X,A8,F4.0,2I3,2F8.0,2X,A8)
IF(IPC.EQ.0) GO TO 1
IF((SYSNUM.NE.SNOLD).OR.(STRATM.NE.STRATO)) GO TO 3
2 I=I+1
CNAME(I) = CTYNAM
JCNT(I)=COUNTY
Y(I)=CPACRE
YAG(I)=CPACRE/AGRI
YPC(I)=IPC
YGPC(I)=IGPC
FLD(I) = FLDACR
GO TO 1
99 IEOF=1
3 CONTINUE
KKK=KKK+1
IF(I.EQ.1) GO TO 7
SUM=0.0D00
FLDSUM=0.0
SUMPC=0.0D00
SUMGPC=0.0D00
DO 4 J=1,I
IF(YPC(J).GT.0.0) SUM=SUM+Y(J)
SUMPC=SUMPC+YPC(J)
SUMGPC=SUMGPC+YGPC(J)
FLDSUM=FLDSUM+FLD(J)
4 CONTINUE
IF(SUM.EQ.0.0) GO TO 7
P=SUM/(SUMPC*25426.56D00)
DO 55 J=1,I
IF(YPC(J).GT.0.0) YP(J)=Y(J)/(YPC(J)*25426.56D00)
YW(J)=YPC(J)/SUMPC
E(J)=(P-YP(J))**2
55 CONTINUE

```

```

FLDSIZ = FLDSUM/I
AA = P * (1.0-P)
XP = FLDSIZ * 22932. / 25426.56
NN=0
DO 54 J=1,I
IF(YPC(J).EQ.0.0) GO TO 54
NN=NN+1
XXX(NN)=YPC(J) * 22932.
YYP(NN)=E(J)
54 CONTINUE
WRITE(2,225) CROP,SYSOLD,STRATO
225 FORMAT('1 CROP = ',A8,2X,'SYSTEM = ',A8,2X,'STRATUM = ',I3)
A1 = P*(SQRT(XP)-1.2732)**2/XP
A3 = P*(SQRT(XP)+1.2732)**2/XP - A1
A2 = 1. - A1 - A3
A = A1*(1.-P)**2 + A2*P**2 + A3*(0.3682-P+P**2)
CALL FITB(NN,XXX,YYP,A,B)
SF=22932.0D00**B
VAR = A*SF
WRITE(2,200) I,P,A,B,SF,VAR
200 FORMAT('/// NUMBER OF COUNTIES IN STRATUM = ',I3/' P = ',F16.9
*   /// A = ',F16.9 /' B = ',F16.9
*   /' SF = ',F15.9 /' VAR = ',F14.9)
DO 11 J=1,I
IF(YPC(J).GT.0.0) PE(J)=A*(YPC(J)*22932.0D00)**B
IF(YPC(J).EQ.0.0) PE(J)=0.0D00
IF(YPC(J).GT.0.0) RE(J)=(PE(J)-E(J))
IF(YPC(J).EQ.0.0) RE(J)=0.0D00
11 CONTINUE
M=0
X=0.0D00
SX=0.0D00
DO 13 J=1,I
IF(YPC(J).EQ.0.0) GO TO 13
M=M+1
X=X+RE(J)
SX=SX+RE(J)**2
13 CONTINUE
IF(M.GT.1) GO TO 14
WRITE(2,500)
500 FORMAT('//,1X,'DEGREES OF FREEDOM=0',//)
GO TO 7
14 XM=M
SD=SX-X**2/XM
SD=SD/(XM-1.0D00)
SD=DSQRT(SD)
BAR=X/XM
DO 17 J=1,I
IF(YPC(J).GT.0.0) Z(J)=(RE(J)-BAR)/SD
IF(YPC(J).EQ.0.0) Z(J)=0.0D00
17 CONTINUE

```

```

        WRITE(2,400)
400  FORMAT(//,1X,'CNTY   GFC       PC       ACRES       PI       WI',
*      (PI-P)**2      PROJECTED      ERROR      ',
*      Z VALUE      CNTY')
        DO 6 J=1,I
            WRITE(2,300) JCNT(J),YGPC(J),YPC(J),Y(J),YP(J),YW(J),E(J),
*      PE(J),RE(J),Z(J),CNAME(J)
300  FORMAT(1X,I3,2(3X,F4.0),3X,F8.0,2(3X,F7.4),2(3X,F10.7),
1(3X,F10.7),(3X,F10.4),6X,A8)
        6  CONTINUE
            DO 21 J=1,I
                PC=YPC(J)
                IF(YAG(J).GE.1.0) GO TO 180
                IF((DABS(Z(J)).LE.3.0).OR.(PC.LE.0.0).OR.
*      (YPC(J).GT.0.5*YGPC(J))) GO TO 21
                YPC(J)=0.0
                WRITE(2,700) JCNT(J),Z(J)
700  FORMAT(//,1X,'COUNTY',I5,5X,'REJECTED',5X,'Z=',F10.3)
                GO TO 21
180  CONTINUE
                YPC(J)=0.0
                WRITE(2,780) JCNT(J),YAG(J)
780  FORMAT(//,1X,'COUNTY',I5,5X,'CROP TO AG RATIO=',F10.3)
                21 CONTINUE
                    NEWPC=0.0
                    DO 22 J=1,I
22  NEWPC=NEWPC+YPC(J)
                    III=NEWPC
                    JJJ=SUMPC
                    WRITE(3,1000) CROP,SYSOLD,STRATO,SNOLD,SUMGPC,SUMPC,
*      A,B,SF,P,VAR,I
1000 FORMAT(2A8,2I3,2F7.0,5F8.4,I4)
                    IF((III.LT.JJJ).AND.(KKK.LE.3)) GO TO 3
                    WRITE(4,1000) CROP,SYSOLD,STRATO,SNOLD,SUMGPC,SUMPC
6,A,B,SF,P,VAR,I
                7  CONTINUE
                    SYSOLD=SYSTEM
                    SNOLD = SYSNUM
                    STRATO=STRATM
                    I=0
                    KKK=0
                    IF(IEOF.EQ.0) GO TO 2
                    STOP
                    END

```

```

SUBROUTINE FITB(N,X,Y,A,B)
IMPLICIT REAL*8 (A-H,O-Z)
REAL*8 X(100),Y(100),MAX
EPS=0.000001D00
I=0
K=10
XK=K
B1=-0.90
B2=-0.10
WRITE(2,200)
1 CONTINUE
DELTA=(B2-B1)/XK
MAX=F(X,Y,A,B1,N)
DO 9 J=1,K
B=B1+J*DELTA
FB=F(X,Y,A,B,N)
IF(MAX.LT.FB) GO TO 9
MAX=FB
BB=B
9 CONTINUE
I=I+1
WRITE(2,100) I,BB,MAX,DELTA
IF(I.GT.20) GO TO 99
IF(DELTA.LT.EPS) GO TO 99
B1=BB-DELTA
B2=BB+DELTA
GO TO 1
200 FORMAT(//,T6,'K',T23,'B(K)',T41,'F(B(K))',T64,'DELTA')
100 FORMAT(1X,I5,6(1X,F20.15))
99 CONTINUE
B=BB
FB=MAX
RETURN
END

```

```

REAL FUNCTION F*8 (X,Y,A,B,N)
IMPLICIT REAL*8 (A-H,O-Z)
REAL*8 X(100),Y(100),A,B,S,Y1,XB
S=0.0D00
DO 1 J=1,N
XB=1.0
Y1=Y(J)
IF((X(J).EQ.0.0).OR.(B.EQ.0.0)) GO TO 10
XB=X(J)**B
10 S=S+(Y1-A*XB)**2
1 CONTINUE
F=S/N
RETURN
END

```